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Eye movement search patterns in the investigation of individual differences in learning from paired associate learning sequences.

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EYE MOVEMENT SEARCH PATTERNS IN THE INVESTIGATION OF INDIVIDUAL DIFFERENCES IN LEARNING FROM PAIRED ASSOCIATE LEARNING SEQUENCES

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A C K N O W L E D G E M E N T S

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ABSTRACT

Statement of the Problem

Eye movement research may provide important insights into the process of differential assignment of students to educational treatments, the goal being the maximization of learning. Whether eye movements are useable as diagnostic and/or prognostic indicators and which eye movements provide the most relevant data, constitutes the problem.

Purpose of the Study

This study analyzed some of the eye movement search patterns exhibited as a subject attempted to memorize simultaneously presented pairs of printed words and line drawings. It is hoped that the search patterns each subject exhibited will provide a useful measure of his idiosyncracy.

The Population.

The seventh and eighth grade and the tenth and eleventh grade students of the Lowell, Massachusetts parochial school system provided the population pool for this study.

Data Collection.

The subject's eye movements were photographed as he attempted to memorize paired associates, printed words and

line drawings, which were projected onto a screen before him. After having observed six slides, the subject was tested for his recall of the pairs. The eye movement pictures were read and the positions of the eye fixations, for each successive one-fifth second, of each four-second visual, were recorded. A computer program searched the data for various eye movement search patterns.

Changer/Nonchanger.

Eye movement preference of each subject for printed word and line drawing were identified for both the stimulus and response quadrants of the Precriterion test and were compared with the ratios of preference for each of the quadrant sets of the Postcriterion test; if the preference for either stimulus or response quadrant sets differed, the subject was classified as a Changer. If neither of the preferences had changed, the subject was classified as a Nonchanger.

Population Subdivisions.

The seventh and eighth grade students were treated as one cell, the tenth and eleventh grade students as another cell. Each cell was divided into a Changer and Nonchanger Subpopulation.

Data Subdivisions.

The data were divided into the first two seconds of

viewing and the last two seconds of viewing, of each four-second visual, of the Precriterion test and also of the Postcriterion test.

Hypotheses and Results.

Hypothesis I. Eye movement search pattern strategies for the seventh and eighth grade and the tenth and eleventh grade subpopulations will correlate significantly with selected Ability variables.

The data empirically supports this hypothesis for future studies in that there were a total of 197 (19 percent) significant, $p < .05$, correlations between the Ability variables and the seventh and eighth grade students' eye movement variables; and a total of 192 (19 percent) significant, $p < .05$, correlations between the Ability variables and the tenth and eleventh grade students' eye movement variables. Analysis of eye movement search patterns seems to hold promise in the quest for meaningful idiosyncratic variables.

Hypothesis II. Eye movement Search Pattern variable scores obtained during the first two seconds of viewing, of each four-second visual display, will vary significantly from those of the last two seconds.

T test analysis produced 108 (23 percent) significant differences, empirically supporting this hypothesis for

future study. This could mean that if some of the information presently being used for analysis in other studies were subdivided, the results might be more useful.

Hypothesis III. The eye movement Search Pattern scores of the Changer and Nonchanger population subdivisions will be differentially related to the Criterion variables.

Hypothesis III is empirically supported for future study in that 28 significant aptitude treatment interactions were identified. This population subdivision has produced aptitude treatment interactions in the last five studies of this series and is recommended for intensive analysis.

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CHAPTER I

PROBLEM

One of the major needs of education today may well be a better method by which to assess the student so that compatible treatments can be devised which will maximize the potential for success and minimize the risk of failure and/or psychological harm. Educators may need to become more aware of the multivariant nature which each student possesses, along with the information store by which he is presently being assessed. Not only are educators assessing only a portion of the individual, they may not be assessing the best portion. Much more needs to be known about the various processing patterns by which individuals operate before learning procedures and environments can be tailored effectively.

Eye movement search patterns as a source of idiosyncratic information.

It is herein contended that eye movement search patterns are a prime source of idiosyncratic information. Societal games, rules and expectations are among the constantly modifying factors acting upon what appears to be an individual's "natural expression." Society has, however, had little to say about the use of the eyes. It

is for this reason that eye movement studies may have intrigue for the investigator of human idiosyncrasies; the patterning of visual processing may provide individualistic trait information.

To date, modes of gathering information from individuals have been oral, written or observational. Each of these methods of response to stimuli tend to be consciously modulated in the mind before the subject commits himself through behavior. A more direct, nonmodulated, noncontrollable response mode would obviously be very desirable. Eye movement analysis may provide another avenue to such information.

The problem to which this study is addressed is the examination of the role of eye movement search patterns in the assessment of idiosyncratic learning differences. Does a person, during the years of interaction with his environment, develop patterns of behavior which could give us clues about the learning mode best suited to that individual? Such patterns of behavior may have predictive value with regard to his future actions.

Since subjects may behave differently in an experimental setting, than in more normal life, an investigator attempting to analyze the overt actions of individuals must be able to deal with possible reactive behaviors, both conscious and subconscious, that could bias the data obtained;

collection of eye movement data, under the guise of normal testing, could allow the investigator to observe physical reactions to visual stimuli unobtrusively and hence less nonreactively. Thus, an eye movement experimenter, having access to what may be an unmediated, quantitative source of subject reaction information, is challenged to devise a catalog describing the relationship of different eye movement behaviors to sets of identified stimuli.

Work on the idiosyncratic eye movements involved in paired associate learning tasks shows growing sophistication and considerable promise (Mackworth, 1938; Coffing, 1971; Caban, 1971; Walker, 1973; etc.). Past studies have tried to determine what a subject looks at during the learning process, when different visual presentation modes are used, and to chart some of the eye movements exhibited during these sight learning tasks. Correlations, which can be drawn from individual differences, have been detected in the subject's choices of directional looking with relationship to success and learning. This study has tried to determine whether eye movement search patterns exhibited while attempting a standard learning task, with visual component aspects, can be classified and correlated with various ability and criterion variables.

Populations.

The seventh and eighth grade students and the tenth

and eleventh grade students used in this study were part of the same school system, the Parochial School System in Lowell, Massachusetts. This provided a total population of 100.

Changer/nonchanger Subpopulations.

Eye movement preferences of each subject, for printed word and line drawing, were identified for both the stimulus and response quadrants of the precriterion test and were compared with the ratios of preference for each of the quadrant sets of the postcriterion test; if the preference for either the stimulus or response quadrant sets differed, the subject was classified as a changer. If neither of the preferences had changed, the subject was classified as a nonchanger.

Limitations of This Study

As Blalock (1964) stated,

> Put simply, the basic dilemma faced in all sciences is that of how much to over-simplify reality. ...there seems to be no systematic way of knowing for sure whether or not one has located all of the relevant variables. Nor do we have any foolproof procedures for deciding which variables to use.

The present study uses a theory modification approach as a reference for the hypotheses. That is, the hypotheses cannot be proven true, they can only be proven false or not be proven false. If a hypothesis is not proven false, under the theory modification approach, knowledge is

generated on the basis of replicability; if the same thing happens every time a statement is tested, it is shown not falsifiable, i.e., is confirmed and becomes knowledge through replicability confirmation. However, one contrary instance is enough to disprove the hypothesis; consequently, if a hypothesis is proven false, modification of the theory is necessary to deal with that instance. The modified hypothesis is then submitted to test. This logic is common to the physical sciences and is now being applied to the behavioral sciences.

The eye movement machine used in the present study was quite sophisticated and accurate; still, there was room for error. All of the students could not be processed in one day or at the same hour. All of the errors obviously cannot be identified, let alone be measured. If all of the errors were in the same direction, quite a large biasing error could result.

The prime purpose of this study was to determine the presence of eye movement search patterns in the data which had been gleaned from the identified population. What, however, constitutes a search pattern? This study has chosen to examine one series from the many other patterns available, i.e., permutations of a series of three successive eye movement pictures taken at one-fifth second intervals. What would happen if the time span

were one picture every one-tenth second, or every one-half second? Could a shorter or longer interval between eye pictures provide more information? These limits, considering the exploratory nature of the study, should be acceptable; but with the clear realization that the results could probably be improved.

In addition to the primary effort of the study, i.e., eye movement search patterns and their potential for idiosyncratic assessment, this study attempts, by replication, to further validate the concept of the changer/nonchanger population subdivision as a viable procedure for generating idiosyncratic information. How the subjects were assigned to the changer/nonchanger categories would seem to be open to considerable analysis. In this study, any subject who changed stimulus side, or response side, eye movement learning mode preference was classified as a changer. To what degree did he change? Perhaps he sought information in the precriterion test from line drawings just fifty-one percent of the time and in the postcriterion test forty-nine percent of the time. Can we in good conscience group this student with another who viewed line drawings ninety percent of the time during the precriterion test and changed to twenty percent during the postcriterion test? This study used the fifty percent cutoff in changer/nonchanger determination due to its

attempt to duplicate the conditions of previous studies regarding the changer/nonchanger question. It is obvious that improved results might be possible if other changer/nonchanger determination criteria were used.

The 55 seventh and eighth grade students were divided into 41 changers and 14 nonchangers. The 45 tenth and eleventh grade subjects were divided almost evenly into 22 changers and 23 nonchangers. Statements based upon a study containing cells of such size are necessarily restricted regarding generalizability.

While external validity for the results is to be hoped for, no external validity can be claimed due to the restricted nature of the population.

Although most of the steps in the data treatment, i.e., collection, transposition, key-punching, etc., were double or triple checked, some small error was probably inevitable. All analytical procedures have some inherent error in the data treatment; it is rarely possible to determine the degree nor the direction of such error.

Delimitations.

This study will indicate the significant variables involved in eye movement/ ability variable interactions, indicate trends and investigate the changer/nonchanger subpopulation effects upon variable interactions, but will not attempt to investigate any particular variable's

interaction with another variable nor attempt to explain why a single variable shows a particular effect. Variables will be interpreted by groups. It should not be inferred that all of the data or population subdivisions possible have been examined. Data treatments and population subdivisions were used which, at the time, seemed logical and practical. Many other courses of action could have been taken which might have produced additional eye movement data.

Hypotheses of the Study

Hypothesis IA.

Eye movement search patterns of the seventh and eighth grade subpopulation will correlate with selected ability variables.

Hypothesis IB.

Eye movement search patterns of the tenth and eleventh grade subpopulation will correlate with selected ability variables.

Using two major populations which vary mainly in age will, it is hoped, not only enhance the understanding of any eye movement search pattern correlations and subpopulation effects, but may also discover the effects of age with regard to these correlations.

Hypothesis IIA.

The seventh and eighth grade eye movement search pattern scores obtained during the first two seconds of viewing, each four-second visual display, will vary significantly from those of the final two seconds of viewing.

Hypothesis IIB.

The tenth and eleventh grade eye movement search pattern scores obtained during the first two seconds of viewing, each four-second visual display, will vary significantly from those of the final two seconds of viewing.

These hypotheses were selected since the novelty-versus-habituation effect of a new visual could conceivably affect the search pattern types exhibited during the first two seconds of viewing versus the last two seconds of viewing. The knowledge of such difference could be useful in eye movement research.

Hypothesis III.

Eye movement search pattern scores of the changer/nonchanger population subdivisions will be differentially related to the criterion variables.

This hypothesis intends to expand the data base related to the changer/nonchanger population subdivision and, by replication, to enhance the understanding of data previously obtained using the changer/nonchanger population subdivision concept.

It is hoped that a systematic hierarchy of individual ability differences can be constructed with which systematic treatments can be interwoven. This research may provide information about which mode of teaching is most conducive to learning and understanding for individual students. Patterns of eye movement scores may, in time, replace some of the assessment methods we are now using for prognosis; failing this, they may make present assessment methods more valid.

Research Format.

Using an eye movement camera, the students' eyes were photographed while the students attempted to learn as many printed word and associated line drawing combinations as possible from the images projected onto a screen before them. Their success in later recalling pairs becomes a measure of the efficiency of their learning. The pictures of the eye movements were read and the movements coded for examination by a computer.

It is assumed that a subject, even if he were aware of the eye movement camera, would have little control over the scanning movements of his eye nor any notion of their analyzability.

If individualized search patterns exist, as literature suggests, then research analysis between search patterns and school marks, I.Q. subscores, efficiency of

learning success and various ability variables may indicate the areas where future investigation may be useful.

If such individualized patterns do not manifest themselves it will be of great interest to those in the eye movement field since reference to such patterns is frequent in the literature. The classification of such patterns and their correlation with learning success, has, to my knowledge, not been done. It is toward the reduction of ambiguity in this area that the present study was directed.

C H A P T E R II

LITERATURE SEARCH

Psychology and education are slowly moving from the stimulus-response mental process paradigm to the recognition of multivariate process modes; we still seem surprised, however, when our subjects fail to produce a common result. The built-in variables in mental processing must be investigated before we can expect to maximize the ability of humans to input, store, recombine and output information and concepts efficiently.

As Cronbach (1957) put it, "Perhaps the most valuable trading goods the correlator can offer ... is his multivariate conception of the world." Bergman and Spence (1944) noted that, at the then present stages of psychological knowledge, the equation:

$$R = S$$

where R = Response and S = Stimulus, needed to be expanded to:

$$R = (S)(I)(M)(P)$$

where the added variables are, I = Innate differences, M = Motivation, and P = Past experience. Woodworth (1938) contributed:

$$S + A = R$$

where A stands for Antecedent conditions.

The concept of multivariability has even shifted from the level of erudite philosophy to the everyday parlance of our most popular periodicals. We read in the August 1, 1969, Time, "There is no average man who always needs a particular dose of this or that ... ."

The present paper reflects another effort to identify additional variables involved during the processing of the individual's world. This viewpoint is succinctly put by Richard E. Snow (1970) when he states:

> The development of new media and instructional technologies is rapidly expanding the variety of educational experiences with which to confront learners and is permitting individualization of many learning situations. Without detailed understanding of how particular instructional treatments relate to individual learner needs, the advertised value of individualized multi-media instruction is an empty promise. The individualization implies classification decisions... . The concept of a single best method of instruction for everyone is like the search for the Holy Grail.
>
> The experimental psychology of learning and cognition has developed to the point where the primary theoretical activity, whether neo-associationistic or cognitive in orientation, concerns the understanding of internal mental events mediating between observed stimuli and overt responses. The use of aptitude variables to represent the psychological and biological history of the organism may be the best and in many cases the only way to gain access to these events. (p. 67)

People scan their environments for a variety of purposes; thousands of people are professionally employed as proof readers, meat inspectors, assembly line inspectors,

aerial photography interpreters, x-ray diagnosticians, sorters, quality control operators, surveillance personnel, etc. In each case, the person executes visual and memory searches appropriate to the task.

In visual search, studied by Jastrow (1892), Dodge, (1901), Neisser (1963), Gould (1965b) and many others, subjects make a series of eye fixations during which they look for one or more target items. Experiments, especially since World War II, have explicitly combined visual search and eye movement studies by recording observers' eye movements during visual search tasks.

Characteristics of the Eye

The significance of eye movements may be better understood if we first consider certain characteristics of the eye. The usual analogy between the eye and camera is quite inadequate, but with several modifications it may suffice for present purposes. Let the camera be mounted on a movable head tripod so that it can be directed up and down, and from side to side. Let the film be such that, in the middle of its area is a small region which is fine grain and color sensitive. The area surrounding this central sensitive spot will consist of coarser grained film with little color sensitivity. (Mooney, 1958). To produce a clear image under such conditions,

one must focus on a target to be photographed in such a manner that the image of the target will fall onto the center of the film. To clearly portray an entire scene would require a montage composed of just the centers of a series of photographs which were taken by moving the center focus over the entire scene. The function of the eye is indeed similar in that the fovea is the area of sharpest image and is surrounded by an area of peripheral vision which is much less sharp. It becomes quite obvious that to process large amounts of material the eye must change its line of sight sufficiently to cover the visual territory. For clear vision, the image of the outside world must be approximately stabilized, at least intermittently, on the retina of the eye. Mackworth and Mackworth (1958), have concluded that there is no appreciable recognition of objects during eye movement. Visual recognition occurs during the fixation pauses between movements. The eyes usually move from one quite clearly defined element in a display to another such element, i.e., the path of the movement and the stopping point seem to be determined before the movement begins. It may well be that the object of each succeeding fixation, in a search task, is perceived peripherally before it is perceived foveally.

Parts of the Eye.

The outer layer of the eye is formed of a tough membrane, the sclera, consisting of firm connective tissue continuous in its anterior part with a transparent membrane, the cornea. The sclera enables the eye to maintain a constant shape and protects its fluid contents. The same function is served by the cornea. Other parts which lie within the protective covering of the eye are: the lens, changes in the thickness of which allows the image to be clearly focused on the fovea; the aqueous humor, which is a transparent fluid behind the lens; the iris, which modifies the diameter of the pupil; the vitreous humor, which is a transparent gel which fills the eyeball; and the retina. The retina is composed of different types of cells: the cones, which are associated with bright light viewing and are color sensitive, and the rods which are much more sensitive to light and thus are used for low illumination viewing but are color sensitive only to some shades of blue. The retina has no rods or cones at the point of entry of the optic nerve, thus we cannot see with this part of the retina; it is often referred to as " the blind spot". The point of clearest vision of the retina is called the macula lutea, it is yellow and lies slightly above the point of entry of the optic nerve. The fovea centralis lies within the macula lutea and is the

part of the retina with the highest resolving power. The diameter of the fovea is about 0.4 mm.

Eye Movements.

Once the eye movement reflex has been initiated or an eye movement decision made, the rate of movement is no longer under conscious control. Brockhurst and Lion (1951) have shown that "If the subject attempts to slow an eye movement it breaks down into a succession of small jumps." Yarbus (1967, p. 211) contributes:

> The human eyes voluntarily and involuntarily fixate on those elements of an object which carry or may carry essential and useful information. The more information (that) is contained in an element, the longer the eyes stay on it. The distribution of points of fixation on the object changes depending on the purpose of the observer, i.e., depending on the information which he must obtain, for different information can usually be obtained from different elements of an object.

Gagne (1969, p. 190) adds:

> Records of eye movements show that the observer's attention is usually held only by certain elements of the picture. As already noted, the study of those elements that give information allowing the meaning of the picture to be obtained. Eye movements reflect the human thought processes so that the observer's thoughts may be followed to some extent from records of eye movements (the thought accompanying the examination of the particular object.) It is easy to determine from these records which elements attract the observer's eye and, consequently, his thought, in what order, and how often.

Studies by Norman H. Mackworth (1968) and A. L. Yarbus (1967) have demonstrated the effectiveness of eye movement technology for obtaining information on visual

strategies reflecting subject attention. Jane F. Mackworth (1970, p. 13) with regard to attention, states:

> The concept of attention has recently returned to favour in psychological and physiological research. It is acquiring not only a qualitative but even a quantitative aspect, with the borrowing of the idea of capacity from information theory, biology and physics. The animal or human is more than a stimulus-response machine; he actively searches for and selects those stimuli that are important to him and he increases their impact by a whole range of physiological and psychological processes.

The actual physical movement of the eyes, in concert, to the spot desired seems to be an involved task. This task requires the coordination of three pairs of muscles which are attached to the exterior of each eye. In each pair of muscles, as one muscle contracts the other muscle must relax to achieve the movement, of whatever magnitude, that is desired. Within each eye the cilliary muscles of the lens must change the thickness of the lens as differences in distance from the subject to the object occur. The feedback from the recognition centers of the brain confirm the arrival on target, or if not on, the brain must coordinate additional movements of each eye to get both eyes on target. This is complicated since the line of sight of each eye must converge at the target, with the line of sight of the other eye. For objects straight ahead there is an equal angle of convergence for each eye, but for objects to the left or right of

center, the angle of convergence differs for each eye; the magnitude of the angle depending upon the distance to the object and the distance that the object is located to right or left.

There are many types of eye movements, however this dissertation is interested in fixations. Fixations are those stops in eye movement whose purpose is to allow the eye (and the brain) to absorb information.

Three assumptions may be central to the use of eye movements in the study of human information processing. First, it is assumed that the duration of an eye fixation on a portion of a scene reflects the relative time needed to process that portion. Second, it is assumed that the sequence of eye fixations indicates some information-seeking strategy. For example, refixation of an item indicates the need to obtain more information about it; the order in which portions of the visual field are fixated indicates the order in which they are processed. Third, if part of the field is not fixated foveally, then that part must be sufficiently distinctive, so that an image of it on the periphery of the retina provides sufficient information for proper, or at least adequate, identification.

Yarbus (1965) comments, "Fixation of attention directed towards an element of a stationary object is accompanied by fixation of the gaze. Subjectively,

this fixation of the gaze is perceived by the observer as fixation by stationary eyes." (p. 127)

In reality, however, the eye moves in three ways during fixation: by small involuntary saccades, equal for the two eyes; by drift, slow irregular movement of the optical axes in which, however, some degree of consistency of position is retained; and by tremor, an oscillatory movement of the axes of the eyes of high frequency but low amplitude. Yarbus (1965):

> It is important during perception of a stationary object that the duration of the independent drift is nearly always adequate to enable the eye to see the fixated element. However, this time (duration) may sometimes be insufficient for the thought process evoked by the perceived element to be completed. Usually, our gaze is directed towards the element about which we think; in which case, a prolonged fixation arises, composed of independent drifts and involuntary saccades. It may be concluded that the same element is seen repeatedly during such a fixation, although the observer usually is unaware of the brief interruption caused by the involuntary saccades. (p. 110)

> Such small saccades are unnoticed and cannot be produced at will. ... large saccades, those by means of which we change our direction of fixation, may be either involuntary or voluntary. There is much factual evidence to show that many large saccades are involuntary... . The main purpose of the saccades is to change the points of fixation, to change the direction of the most highly developed region of the retina (the fovea) to a particular element of the object of perception. (p. 145)

> The human eyes voluntarily fixate on those elements of an object which carry or may carry essential and useful information. The more information contained in an element, the longer the eyes stay on it. The distribution of points of fixation on the object

> changes depending on the purpose of the observer; i.e., depending on the information which he must obtain, for different information can usually be obtained from different parts of an object. The order and duration of the fixations on elements of an object are determined by the thought process accompanying the analysis of the information obtained. Hence people who think differently also, to some extent, see differently. (p. 211)

Head movements, blinking movements of the eyes, saccades, drifts and tremors during the fixation of an element of a stationary object, all create a certain mobility of the retinal image and thereby prevent the formation of an "empty field." However, the formation of an "empty field" in intervals between saccades is prevented mainly by the drift of the eyes.

> In man under natural conditions the retinal image is never stationary relative to the retina, and if a strictly stationary and unchanging retinal image is created artificially, the eye ceases to see. In other words, within any object of perception remaining strictly stationary relative to the retina and unchanging in time, after about 1-3 seconds all visual contours disappear (the resolving power of the eye rapidly falls to zero)." (Yarbus, 1967)

Yarbus also states:

> Some readers may think that during perception of stationary objects the human eyes are able to perform smooth pursuing movements in addition to saccades ... this view is incorrect. Although subjectively the tracking movements of the eyes seems smooth and uninterrupted, they are in fact, composed of discreet stops, (called fixations) and small saccades." (p. 104)

Drifts differ from saccades in their speed, i.e., saccades exhibit speeds of 200-500 minutes of angle per second,

whereas drifts are much slower, averaging 5 minutes of angle per second. (E. Llewellyn Thomas, 1963)

Previous Eye Movement Studies.

Previous eye movement studies have established some basic information.

The studies of Enoch (1960) revealed that people read in a series of stops.

Gould and Schaffer (1965) state, "Since no perception occurs between points of fixation, the eye movement parameters are: number, duration and location of eye fixations." Gould and Schaffer also found that the duration of the fixations, not the number, varied significantly as the task became more difficult.

Taylor, et al. (1960) reported, "It is important to realize that eye movements themselves are not greatly subject to conscious control." Carmichael and Dearborn, (1947) " ... The normal reader cannot 'voluntarily' control the number of his fixation pauses, regressive movements or the other actions of his eyes."

Miles Tinker (1946) reported the minimum fixational eye pause time to fixate and identify a letter was .157 seconds. Brandt (1944) concurs with, "The human eye makes an average of four fixations per second."; i.e., .25 seconds each, minus the time for movement. Although Brandt also admits frequent observation of fixations of

over one second in length. Ford, White and Lichtenstein (1959) found the average of fixations at .27 seconds.

Tinker (1946) quotes Bayle (1942) as classifying fixational pauses into six patterns:

1. Adjustment after the first fixation in a line.
2. Adjustment within a line when the span of fixation is overreached in too long a forward move.
3. Regressions for verification.
4. Regressions during work analysis.
5. Regressions for phrase analysis.
6. Regressions for re-examination of a whole line.

According to Tinker, Bayle found that regressions were caused by a need to complete perception and by difficulties in interpretation due to failure to recognize the meaning of a word or failure to connect the meaning with a context. Bayle states that, " ... regressive pauses are necessary parts of the reading process in analytical reading." The implications are that we can expect regressions in order to clarify the identity of the scanned material within the context of the other material to be memorized. Rehearsal in memorizing material is another factor we must consider. However, Bayle was investigating reading eye movements, not eye movements in a search and memory procedure.

Bushwell (1935) in a study of adult reading, emphasized that fixation span (time) and span of recognition (line length) are important indices of reading maturity, i.e., narrow recognition span indicates immature reading habits.

Schmidt (1966) found that the number of fixations and regressions could be reduced, and that comprehension, duration of fixations and span of recognition could be increased, with proper training.

Grether (1950) noted that during the reading of instruments, pointers which deviated from the norm could be detected without direct fixation.

Tinker (1946) found that the percent of reading time devoted to moving, i.e., between fixations, ranged from 5.3 percent to 9.6 percent, with an average of 7.3 percent of the total reading time spent in moving. The more careful and analytical the reading, the shorter the relative time taken by movements. Ford, et al. (1959) found that eyes fixated "approximately 85% of the time," attributing the deviation of his results from those of other studies to the complexity of the material.

In part, the present study replicates Coffing's (1971) methodology and procedure. Coffing used the paired associate learning materials developed by Rohwer (1967) and obtained stronger results than Rohwer's in the

same direction. Both studies showed that the presentation of line drawings of objects was significantly more effective than the presentation of printed names of the objects, for subjects in the learning situation.

Rohwer's experiment was designed to assess the effectiveness of different audio-visual presentations in a paired associate efficiency of learning paradigm with 96 third and sixth grade children. The visual stimuli were either line drawings of objects or the printed names of the objects and were simultaneously presented with a sound track labeling the objects in a sentence structure such as "the bat strikes the ball."

Coffing used Rohwer's visuals and found a significant main effect for line drawing vs. printed word, presentations. Effects were examined by a two-way analysis of variance with repeated measures, using order and mode of presentation as the two independent variables. Thus, Coffing confirmed Rohwer's argument that pictorially supported audio-visual associative learning is superior to printed word supported audio-visual associative learning. Coffing attributed his stronger results to increased control of extraneous variables.

Visual Perception.

In summary, then, there are two basic stages in visual perception. First, the object must be focused

onto the observer's retina; and second, this focused image must be interpreted within the observer. (Anderson, 1958) For perception of detail, in a task such as reading, it is necessary that the focused image fall on the fovea, for only at the foveal portion of the retina is clear, sharp vision possible. The area covered by this foveal vision is smaller than is usually realized, as the fovea subtends only about two degrees of angle. (E. Llewellyn Thomas, 1963) The area which is clearly perceived in a display held at a distance of 30 inches from the eye, is a circle of just over 1 inch in diameter.

Eye Movement Investigation Techniques.

The ancients studied overt eye movements during periods of reading, study and concentration. Not until the 19th century, however, and the application of more advanced technology did investigators become aware of the minimally overt eye movements which precede and follow the larger movements. Once aware of these lesser eye movements, researchers attempted to develop methods by which the eye movements could be directly and quantitatively related to the items being viewed. Eye movement investigation techniques fall into several basic categories:

1. The direct observation of an eye by an observer. Since the important eye shifts, for sight and search,

occur very rapidly and have great acceleration, direct eye observation does not yield much important information. For detailed study some permanent record of the eye movement is preferable.

2. Latent image observation.

As early as 1858 Hermann von Helmholtz wrote an explanation of the causes of latent images; to this date we are still looking for a complete explanation. Latent images occur constantly but are usually ignored by our processing systems or covered by subsequent, more vivid, visual exposure. A latent image, as the name implies, is an image observable, to the subject, after the stimulation of the viewed object has been removed from his visual field. After exposure, latent images can be observed with the eyes closed or open, and can, under proper circumstances, remain visable for up to 20 minutes. (Scientific American, July, 1964, p. 24-35)

Yarbus (1965) : "Since the after-image is strictly stationary relative to the retina, the apparent movement of this image on the screen corresponds directly to the movements of the eye. Knowing the distance between the eye and the screen, it is easy to ... determine the eye movements performed during fixation with rough accuracy." (p. 211)

The latent image technique depends on the subject's

recall of the latent images with relation to fixed markers in his visual field. While latent image investigations were important as a primitive tool for the study of eye movements, this method has been replaced by methods employing devices which would provide a permanent record of a series of ongoing eye movements and in which the degree and direction of movements could be accurately measured.

3. Mechanical eye attachments.

Some seventy years ago, E.B.A. Dellabarre, of Brown University, used a plaster cast of the cornea to fasten lightweight levers to his own eye and record, by kymograph, those eye motions which were exhibited during sight tasks. The resulting recordings were squiggle lines, the peaks, and spacing between the peaks, representing the movements of the eye during various visual tasks. Though crude, this experimentation encouraged sclera (white of the eye) mounting of similar equipment in future explorations.

4. Reflection of a light beam from a mirror "attached" to the sclera of the eye.

The attachment of a mirror to the sclera at the front of the eye, is a method which allowed light reflection using low light spot intensity and thereby reduced involuntary shying away from the spot. The correlation of the line of sight and recorded eye movements is usually

very good with this method, but the trauma associated with the sclera mounted mirror must be recognized as a major idiosyncratic variable.

In 1925, Gosta Dohlman, at the University of Upsala in Sweden, attached a mirror to a subject's eye with a suction cup. Yarbus (1965) has used suction cups for years to contribute indefatigably to the eye movement study field. Some investigators have even attached small light bulbs to the sclera (Fender, 1964).

Contact lenses, with mirrors attached, seemed logical candidates for eye movement studies. However, unless the contact lenses are very carefully fitted, they tend to slip about too much to produce consistently valid data. Nonetheless, Ditchburn and Ginsborg (1952) and Riggs, Ratliff, Cornsweet and Cornsweet (1953), used contact lenses in their eye movement studies. Ganz and Wilson (1967), working with Rhesus monkeys, used contact lenses and encountered problems which bear mention as illustrative of this type of investigation:

> The acceleration of the eye, from a position of rest to one of maximum velocity, is surprisingly great. Necessarily, an object having mass will show inertia. Since the lens rests on a film of fluid covering the eye, this inertia causes the lens to lag behind the eye in its motions. Such lag would induce changes in the (observed) retinal position approximately equivalent to the magnitude of the lag, measured in degrees of angular rotation.

Ganz then follows with a very involved solution for the determination of the lag, which solution, aside from its inherent complication, is, to say the least, suspect.

5. Pictures of eye movements.

(a) Pictures of the eye without corneal reflection of the scene, for the purpose of observing the types and extent of eye movements, with little regard for the exact foveal point of observation of the scene.

Eye pictures by movie or T.V. camera are excellent for observations regarding the types, directions and extent of eye movements. Brandt (1940) reported having developed eye movement recording techniques which employed a camera with slowly moving film, upon which were recorded both vertical and horizontal eye movements; for its time this was a major step in eye movement technology. In Brandt's eye movement tracking technique, a small light was aimed at the eye and the reflection of this spot from the cornea of the eye was then passed through lenses onto a photographic film. Correlation between the spot on the film and the area of the scene upon which the eye was focused was achieved by various adjustments and was fairly accurate. The film which resulted from this technique showed a continuous line squiggle, representing the path which the light spot took on the film. After a subject viewed the scene; i.e., picture, pattern, number matrix,

etc., the film would be developed and superimposed over the observed picture, pattern or number matrix, which the subject had been viewing. Brandt's technique was considerably easier than previous methods, which recorded vertical movements separately from horizontal movements. Brandt (1940) states, "The analysis of ocular performance by means of photography is thus a promising field of research in many respects."

Upon surveying eye movement studies, he states, "In every case, new information has been revealed leading to the general conclusion that eye movements have a functional relation to the central processes of the learner."

Taylor, et al. (1960) observed, " ... Analysis of eye movement photographs reveals data that is objective, with factors that are directly countable and measureable. Further objectivity results from the fact that the tests record directly the subject's activity rather than a written or oral expression of this activity."

(b) Pictures of the eye with regard to the exact portion of the scene which is being foveally observed.

This method, which is the one used in this study, provides a film or television tape record of the eye, its movements and the reflection of the scene at which the eye had been aimed. When an experimenter views such a recording, the scene is observed as it was reflected from

the cornea, which is the membrane which lies just in front of the pupil of the eye. The location of the reflected scene, relative to the center of the pupil, indicates the area of the scene that was being foveally fixated, i.e., that portion of the scene which was in sharp focus at that moment. This method is excellent for studies investigating eye movement and fixation.

Reflection of a bright spot from the cornea of the eye which is then superimposed on a picture of the viewed scene, either by mechanical or electronic means, is another eye movement recording process. In 1962 Mackworth and Llewellyn Thomas reported their improved eye marker system, which recorded the scene, the eye movements and the eye fixations within the scene. Briefly, this consisted of a small motion picture camera, or T.V. camera, which photographed the scene which the subject was viewing. A mirror, near the eye, transmitted a spot of light from the surface of the cornea to the camera. This spot was then superimposed on the permanent record of the scene, either mechanically or electronically depending on the equipment. The permanent record, and in the case of T.V., the T.V. monitor also, would show where the subject was looking, at any given moment, by the location of the spot of light. The eye spot is actually a magnified image of the corneal reflection of a light beam from a small

electric bulb which is located near the eye. This corneal reflection moves as the eye moves and, within about 15 degrees of the midline of sight, its movements are well correlated with the movements of the eye itself. The size of the spot on the scene is about two degrees of visual angle and thus approximates the area of the scene which is focused on the fovea within the eye; that is, it represents the area of the scene which the eye is viewing at that moment with distinct vision. It is thus possible to make observations regarding not only where a subject looks but also what types of information he can perceive without clear (foveal) vision.

John Gould's and Amy Schaffer's (1965a) experiences with the Mackworth eye-marker system are typical, interesting and informative.

> A considerable number of problems were encountered before we were able to obtain accurate and reliable eye movement records using the corneal reflectance method in general and the Mackworth eye-marker system in particular. Some of these involved modifications of experimental tasks, some involved recording procedures, and some a thorough analysis of the geometric optics of the situation. It was felt that the following facts might be of interest to future investigators.
>
> (1) Naturally head movements must be eliminated since a movement of .75 mm. causes loss of calibration between subject's eye movement and its indicated position. (Mackworth & Mackworth, 1958)
>
> (2) All corneal reflectance methods suffer from the inherent astigmatism of the cornea itself due to its torroidal surface. This takes two forms.

First, the vertical and horizontal meridians of curvature differ, the vertical having greater curvature. Secondly, individual eye variations, such as slight undulations and humps and other corneal asymmetries occur on the cornea and these are unique to each subject.

(3) The more intense the light beam projected onto subject's eye, the more the eye waters and blurs the reflected spot.

(4) While it has been suggested (Mackworth, et al., 1958, 1962) that the eye-marker apparatus is suitable for fields up to 28 to 30 degrees, we found that fields larger than about 20 degrees compelled head movements. The 13 to 14 degree divergence of the right eye needed to fixate the right edge of such a large (30 degree) field was perceived as strain. We found that even when using a 15 degree field we had more success in eliminating what apparently were head movements by shifting the entire visual field 2 to 3 degrees to the left.

(5) Even assuming conjugate movements of the two eyes, recording from one eye does not accurately reflect the movement of the other eye. That is, in symmetrical convergence on a frontal plane object located midway between the two eyes, each angle of convergence is the same. However, when the head is kept rigid and an object is fixated to the right of the midline, the angular distance moved by the left eye is greater than that of the right eye.

(6) The success in obtaining records varied widely among subjects and also within a particular subject from day to day; consequently some subjects must be dropped and others called back again after a day of unreliable recording.

6. Recording eye movement by means of photocells.

Stork, et al. (1962) reports a method of eye tracking using two bulbs and two photocells. This method resulted in eye movement data which could be related to the visual scene with only limited accuracy.

7. Electro-sensing devices (Propriosensing).

The basis of this system is that muscles, in order to contract, must be energized by a small electric current. By attaching electrosensors to the head near the eye muscles, a polygraphic output can be obtained showing which muscles are being contracted and to what degree they have been stimulated. Besides being graphed, the data can be directly fed into a computer which can electronically introduce a light spot onto a T.V. monitor screen in such a manner that the position of the spot, representing the area of foveal focus, and a T.V. picture of the subject-observed scene, can be superimposed and well correlated.

Individual Differences.

Individual differences have been defined as "any characteristic of the individual that increases (or impairs) his probability of success in any given treatment." (Cronbach, 1969, p. 7)

Eye movement studies may well be a reflection of cognitive processes other than just inputting information during visual search. Studies have revealed considerable eye movements during sleep and during the solving of mental mathematical problems. Future studies may well provide some answers regarding cognitive process and define relationships between eye movements and some of the inter-

vening variables involved.

Cronbach (1957) states, "Ultimately we should design treatments, not to fit the average person, but to fit groups of students with particular aptitude patterns." (p. 68)

Snow (1968) submits, "The objective is to study variation in cues across units (days, weeks, etc. or lessons, courses, etc.), to discover natural organization (by the individual) of such cue variables, and to relate to these the more basic behavioral characteristics of the human beings involved."

Paisley (1964), in his fascinating paper on distinctive styles exhibited in art, music, and literature, contributes the following:

> When authorship of a work is disputed, we may assume that historical evidence is inadequate. Therefore, clues must be sought in the text itself, usually in the style of work. Style, however, is a concept often embracing the ineffable qualities of a communicator's output. ... The unique character of a work may be defined in terms of successive decisions made by the communicator as he chooses from a repertory of symbols.

The decisions referred to are not conscious decisions, for the acts of style referred to are not the overt, obvious mannerisms but rather the hidden idiosyncrasies or "modus operandi" of the originator in question. It is most interesting that while the originator is making "successive decisions," he is, unbeknownst to himself,

imprinting his style upon the work. The same thing may be true of idiosyncratic eye movement, i.e., that each individual scans objects in a distinctive manner. Can this distinctive pattern be a reflection of an internal cognitive pattern or aptitude? This is the conundrum. Paisley (1964) continues:

> There has been surprising consensus ... concerning those encoding habits which clearly distinguish a communicator from all other communicators with superficially similar output. This consenses ... favors minor encoding habits which are inconspicuous in the work and do not carry the burden of meaning.
>
> Indeed, converging evidence now suggests that all human communicative behavior exhibits two types of idiosyncrasy deserving study. The first is the obvious idiosyncrasy of complex constructions ... The second type of idiosyncrasy is that of minor encoding habits..."

Cronbach (1957) adds, "All organisms adapt to their environments, but not equally well." (p. 674) To this must be added, not necessarily in the same fashion. The degree to which humans adapt to the environments they hold in common is a variable for which the author hopes eye movement pattern analysis will provide a measure. Eye movement studies hold a great advantage since, in sighted persons, a major portion of input information is obtained through this sensory channel.

Glaser (1967) states, " ... as children grow older they begin to generate their own forms of mental elaboration...". Rohwer's work suggests that individual

differences, related to children's backgrounds, influence the way in which they carry out cognitive processes. (Rohwer, 1970)

Yarbus (1967) reasons that, with regard to the sequence and time spent on various features of a viewed object, it is most

> ... natural that the sequence and duration of fixations of the elements of the object (being viewed) are determined by the thought process accompanying the assimilation of the information. Persons who think differently observe differently. (p. 97)

Eye movement search patterns then, seem to reflect basic mental operational procedure which should not be easily changed by environmental fluctuations. This modus operandi should be a permanent imprint within an individual, which would rank eye movement search patterns in a class of basic operations which, being unconsciously controlled, are less variable than other traits of which the subject might be aware.

Patterns and Patterning.

Patterns may be defined as: a recurrent series of events. Not only is the entire universe composed of patterns of different sizes and dimensions, but man spontaneously perceives both his world and his experiences as patterns. Man not only recognizes patterns but tries, as much as possible, to reduce his everyday environmental encounters into patterns so that he can react with patterned

responses. This patterning of many stimulae and responses affords the mind considerably more time for the cognitive processing of other stimulae which, due to their novelty, do not fit mental templates. It is not surprising therefore, that there could be eye fixation patterns reproducing the "Gestalt" of the scene, a finding which has been demonstrated by Yarbus (1960). Buswell (1935) corroborated peoples' stylization of search patterns when he reported "wide individual differences in both the general pattern and duration of the fixations." He also reported that differences in duration are more related to the characteristics of the individual than to the characteristics of the picture. Enoch (1960) divided the search pattern into two phases:

1. An orientation, i.e., a basic search.

2. The specific search phase.

> During the orientation phase, (a subject) goes through a characteristic pattern which he repeats with remarkable similarity in other displays having different physical qualities. Most patterns were spirals (in and out) up and down, laterally back and forth, a closing square pattern, etc. ... . Some subjects used a nondirective pattern.

E. Llewellyn Thomas (1963) adds:

> In eye movement studies the most important variables appear to be the search pattern, the distribution of the visual fixations within the scene, and the duration of the fixations. Different subjects acapted different patterns of search, with some tending to make sweeping eye movements from one side to the other while other subjects tended to center around

> certain areas using comparatively short movements. The very first part of the initial search pattern will consist of an attempt to grasp the whole display to allow complete identification.

Mooney (1958) has shown that a large part of the recognition process takes place during the first instant of exposure.

> This part of the pattern can, therefore, be expected to be a function of the display itself and of the search habits of the subject. The details of the fixation times in each individual case are almost impossible to express quantitatively. However, the individual plots all suggest individual patterns in which the subject fixates for a longish period of time and then makes a number of short fixations before making another longer one.

Information Processing and Eye Movement.

The foregoing paragraph suggests a process of rapid intake of the information which is being processed. In this connection it is interesting to read of studies by Broadbent (1960) and others, which suggest that the brain is acting as a single communication channel, and not as a multiple pathway as is often thought. Moreover, the brain, it seems, deals with the sensory information in short groups and new information is only taken in when the preceding group has been processed.

> It is possible, therefore, that the duration of each eye fixation is related to the quantity of information generated by that fixation point in the scene and that the duration is an expression of multiples of information quanta. (Broadbent, 1960)

Taylor, et al. (1960): " Through an analysis of the patterns his eye make, we learn much about the subject's

organization and effectiveness...".

Brandt (1940):

> Since the eye movement technique analyzes more directly the process accompanying mental states, it may gain for teachers and supervisors a clearer understanding of the learning process and furnish a basis for diagnostic and remedial procedures. Proper direction and instruction can only follow when the process itself is known. By means of ocular photography it should be possible to verify the assumption that achievement presupposes an efficient process.

Many eye movement studies are indeed directed toward this end. Gould and Schaffer (1965a), reported that all subjects' eye movement patterns, in structured tasks, were quite similar, "The center of the display was first fixated, then the top row, then the bottom row." They then stated a most important finding, "The number and pattern of fixations were independent of experimental variables."

Brandt (1940) concurs,

> ... the author found three properties of eye movement when a symmetrical field is under observation. (1) The mean of the initial fixation is located at a point above and to the left of the center of the observed field, while the second and third fixations are located above and to the left of the first. (2) There are more fixations on the upper half than on the lower, and more on the left half than on the right (these results confirm, by a different method, Dallenbach's (1936) findings). (3) Horizontal movements exceed vertical both in frequency and in total excursion distance.

Grether (1950) working with the reading of instruments found a "preponderance of fixations on the upper

left half of the panel."

Brandt (1940) reports,

> The ocular patterns show the relations which exist for the learner among the materials presented. Organization, in this sense of the term, is no longer an abstract idea. It has meaning in terms of ocular performance which reveals the method and procedure employed by the learner in acquiring certain types of information: how he attacks the problem, how he organizes his data, and how he distributes his efforts." (The underlines are mine.)

Grether (1950) found the first fixation to remain fixated longest.

Ford, et al., (1959) reports, " ... the third generalization which can be made on the basis of current findings is that observers do not distribute their fixations evenly over an area to be searched."

The preceding serve as the basis for the use of search patterns in this dissertation. Individualistic behavior, as expressed in eye movement pattern idiosyncrasies, may be of unique interest. The question whether such atypical behaviors occur and can be correlated with learning variables constitutes the problem at hand.

Perception and Cognitive Processes.

Gould (1965) reminds us that " ... looking is not seeing." According to the Travers (1966) and Broadbent (1958) perception model, perception begins with the omission of redundant or extraneous detail from the picture being transmitted to the brain. This is accomplished by the

sense organ itself and the peripheral nervous system. Further compression of information is achieved by categorization. According to Miller, Galanter and Pribram (1960), this compressed information is then compared with stored templates of previous inputs, in an effort to detect differences and similarities and thereby possibly update, i.e., modify, the previously stored template and/or possibly create additional templates. Having thus perceived, a person continuously adds up these perceived items into thought units until, in the light of past experience, ideas, judgments, and decisions, he evaluates this vast composite and stores the result and/or acts upon a conclusion.

A word of clarification regarding the meanings of: cognitive style, process variables and ability variables. Cognitive style, i.e., the manner in which a person thinks, is composed of the process variables which input, order, distribute, reorder, formulate and eventually, in some manner, at some time, express a result. Ability variables are those abilities of the individual which, due either to heredity or to environmental programming, allow an individual to "process" certain types of input or output differently from another individual.

Eye Movement Indices of Cognitive Behavior.

The study of eye movements in relation to cognitive

activity has markedly increased during the last ten years, and some of these studies bear importantly on the processes of instruction and communication. In the analysis of electrical information systems, the system effect (noise) and the efficiency of the system in question, can be computed. The analysis of human information processing, following the same basic line of reasoning, seems vastly more complicated. With much difficulty, the input and the output to the human system can be measured. The biggest problem, at the moment, is to assign roles of process to various components of the organism with which we are concerned, and to clarify the methods of their functioning. Eye movement search patterns or measurements may provide information regarding rates of mental process and may aid in measuring types of intelligence not yet recognized.

Nadel (1939) submits, " ... we should not so much be examining and measuring degress of intelligence as analyzing <u>different types</u> and <u>qualities</u> of intelligence."

Some relationships between I.Q. measures and eye movement measurement variables have been shown by Simpson (1942).

Rosner's (1972) work indicates that competence in visual and auditory perceptual processes is differentially related to academic achievement in arithmetic and reading.

He has also shown that these processes can be effectively taught to children.

It may be that eye movement search patterns are a reflection of some ability variables inherent in the individual, which by the very act of interacting with his environment may have been modified in such a manner that their study will yield insightful, useful knowledge.

Cronbach (1957) adds further, "I believe that we will find those (yet to be discovered) aptitude measures to be unlike our present aptitude measures."

Snow (1970) delineates the problem nicely when he states, "The main groupings (categories for investigation) are intellectual abilities, personality traits and interests, and cognitive styles and preferences." (p. 69) "The newest and perhaps most intriguing category of individual differences is a poorly defined group called cognitive styles." (p. 72)

Eye Movement and High Scholastic Performance.

Anderson, et al., (1958) concluded "High performers exhibit fewer fixations and regressions than low performers ... . High performers have a total duration of fixations and regressions which is less than low performers... ."

It follows, therefore, that if correlations between search patterns and I.Q. subscores exist, a non-verbal, non-interventionistic method of scholastic ability testing

may be added to the diagnostic aids now available to the educator.

Enoch (1960) contributes, "Subjects of low achievement devote nearly twice as much time, 2.05 sec., to acquire one unit of subject matter, as do their superior competitors, who devote only 1.17 sec. to achieve a unit of the same type of subject matter." This corroborates the findings of previous investigators, however, more to the point of individual search patterns, he continues:

> Conditions which influence and determine the character of ocular patterns in learning situations are the intellectual capacity of the individual, the character of the observed field, the nature of the problem, the past experience of the learner, and the purpose of the learner at the time of observation. The ocular patterns show the relations which exist for the learner among the materials presented. Organization in this sense of the term is no longer an abstract idea. It has meaning in terms of ocular performance which reveals the method and procedure employed by the learner in acquiring certain types of information; how he attacks the problem, how he organizes his data, and how he distributes his efforts.

Guba and Wolf (1964) stated, "... a sizable correlation between some of the eye movement indices of subjects in the pilot study and intelligence as measured by the California Test of Mental Maturity." Thus, intelligence appears to be a variable which exhibits a degree of relationship with some eye movement indices.

A search for meaningful idiosyncratic eye movement search patterns, in the light of the foregoing arguments,

seems most compelling.

CHAPTER III

PROCEDURE

Subjects

The subjects involved in this experiment were drawn from the St. Joseph's School system of Lowell, Massachusetts. Fifty-five seventh and eighth graders were treated as one population and forty-five tenth and eleventh grade students were treated as a separate population. The research design and experimental procedure were identical for both groups. The environmental factors were as similar as possible even though the two populations were tested in the elementary school building and the high school building, respectively.

Experimental Design

The experimental design is displayed in Figure 1. The testing proceeded as follows: Ability tests, Precriterion tests, Line Drawing Criterion tests, Printed Word Criterion tests, Postcriterion tests.

Ability Tests.

All seventh and eighth grade students were administered the mathematics and reading portions of the "Science Research

	Ability Tests	Precriterion Presentation Preference Eye Movements	Criterion Measures Single Paired Associate Learning Trial Sequences		Postcriterion Presentation Preference Eye Movements
7th & 8th Grade	E.T.S. "French" Ability Tests & S.R.A. Reading and Math Scores	Picture and Word Concomitant Presentation 6 Pair Learn Test	Picture Only Presentation 12 Pair Learn Test	Word Only Presentation 12 Pair Learn Test	Picture and Word Concomitant Presentation 6 Pair Learn Test
10th & 11th Grade	E.T.S. "French" Ability Tests & S.R.A. Reading and Math Scores	Same As Above	Same As Above	Same As Above	Same As Above

Test Scores

Film Recording of Eye Movements

Efficiency of Learning Test Scores

Figure 1. EXPERIMENTAL DESIGN

Associates" (S.R.A.) test. The Differential Ability Test (D.A.T.) subscores provided standardized information for all of the tenth and eleventh grade students. These are pencil and paper tests and were given by the school system as part of their ongoing testing program. The scores for these tests were recorded from the students' school records.

All subjects were administered Basic Ability tests taken from the Educational Testing Service (E.T.S.) test kit (French, Ekstrom, and Price, 1963). This test is a paper and pencil test and was administered, in the classrooms, to the entire classroom population at one time, prior to any eye movement tests of this study. The tests in the E.T.S. kit are suggested for use in factorial studies where representation is desired for any of the below mentioned ability factors. It is intended that the use of the test kits for this purpose will facilitate interpretation and the confident comparison of one factor study with another. The usual reliability, norming, validity, or other information ordinarily expected in a test manual have not been included because these tests are suggested for the single purpose of factorial research. The Ability tests chosen from the kit (French, et al., 1963) were as follows:

1. Gf-1, Hidden Figures Test. This test involves the ability to keep one or more definite configurations

in mind, in order to be able to make identification in spite of perceptual distractions.

2. P-3, Identical Pictures Test. This test involves the speed of finding figures, making comparisons and carrying out other very simple tasks involving visual perception. It was adapted from a test originated by Thurstone. It is especially concerned with evaluating speed of novel form discriminations.

3. Ss-1, Maze Tracing Speed Test. This test involves speed of visual exploration of a wide and complicated spatial field.

4. V-3, Wide Range Vocabulary Test. This test involves the ability to understand the English language with reference to the size of vocabulary comprehended.

5. Vz-3, Surface Development Test. This test involves the ability to manipulate or transform the image of spatial patterns into other visual arrangements.

6. Ms-3, Letter Span-Auditory Test. This test involves the ability to recall perfectly, for immediate reproduction a series of items, in this case letters, after only one presentation of the series.

The first four of the above tests consist of two parts. For the purpose of this experiment, each part was considered separately. Thus, there were a total of ten ability measures derived from the Kit of Preference Tests for Cognitive Factors.

At some time following the E.T.S. Ability tests, the students were individually tested with the eye movement machine. This machine was located in a room provided by each school for this exclusive purpose. The subjects were scheduled according to a list which was prearranged by the principal and the teachers.

Precriterion Test.

The Precriterion test consisted of 6 concomitant line drawing and printed word object pair visuals, each with an image consisting of two printed words and two line drawings. (See Figure 2). On the left side of each visual display there was a line drawing and a printed word depicting the same object, e.g., bat. On the right side, there was a line drawing and a printed word depicting another object, e.g., cup. The left side was known as the stimulus side and the right side was known as the response side. This presentation was followed by a recall test with the 6 left objects of the pairs presented randomly as the test stimuli.

The subject's objective was to remember which response object was paired with which stimulus object. All of the subject's responses were oral and were taped for later analysis.

Printed Word Criterion Test.

The Printed Word Criterion test consisted of 12 object

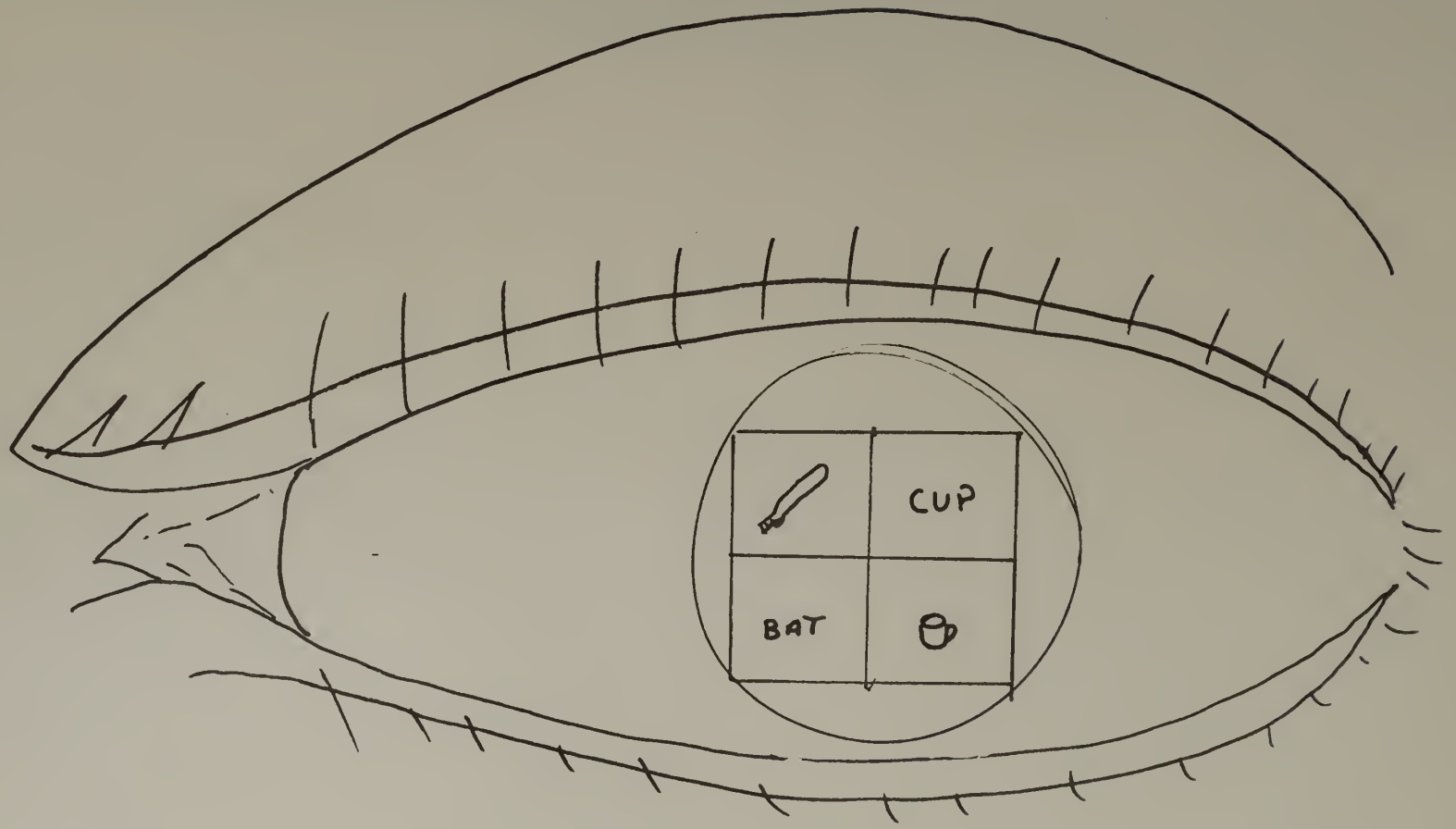


Figure 2. Reflection of the Viewed Display Shown As it Would Be Seen Superimposed Over the Pupil and Iris, Reflected From the Cornea.

printed pairs to learn, followed by the twelve left objects of the pairs, used as test stimuli.

Line Drawing Criterion Test.

The Line Drawing Criterion Test consisted of twelve object line drawing pairs to learn, followed by the twelve left objects of the pairs, used as test stimuli.

Postcriterion Test.

The Postcriterion test consisted of six concomitant line drawing and printed word object pair visuals, followed by a recall test with the six left (line drawings or printed words) object pair visuals, presented randomly, as the test stimuli. The recall test was intended to evaluate the efficiency of learning under these particular learning conditions. In this case it was also used to determine if any changes in experimental behavior had occurred as a consequence of the exposure to the criterion tests.

Eye Movement Data Collection

Introduction of Subject to the Eye Movement Machine.

After a subject entered the testing room he was greeted by the examiner as follows, "Hello, you are going to see a slide show. Please be seated and look into the opening." The chair height was adjusted for each subject. Once seated before the eye movement machine (see Figure 3), his head

Eye Movement Recording Apparatus

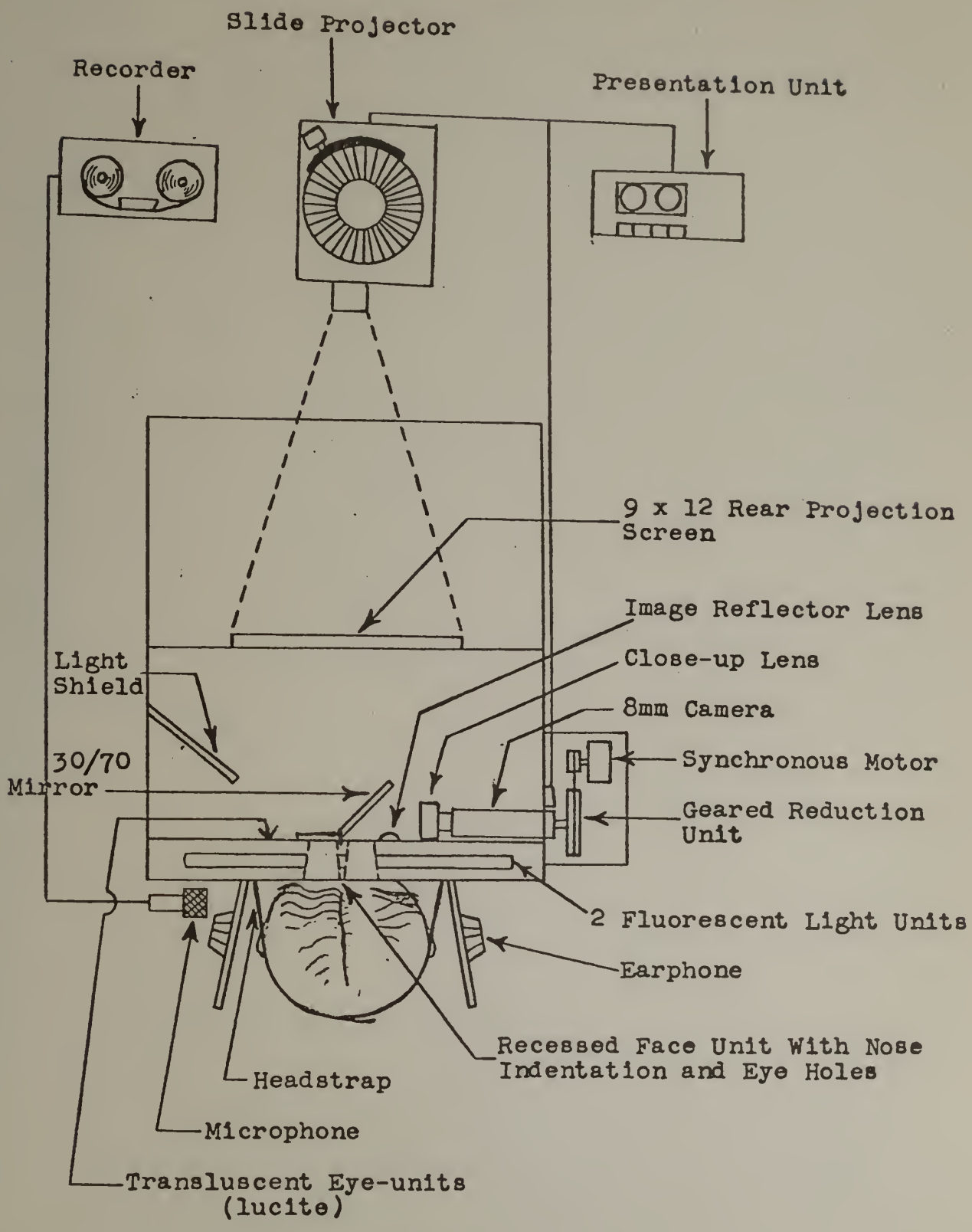


FIGURE 3

strap was adjusted, to reduce possible head movement, and the machine was started. A recorded voice began the instructions. (See Appendix I). The eye movement machine for the next seven minutes then automatically proceeded through the visuals and audio of the Precriterion Test, Printed Word Criterion Test, Line Drawing Criterion Test, and the Postcriterion Test.

Eye Movement Recording.

The eye movement machine used in this study provided clear pictures of the subject's eye as well as a clear picture of the visual the subject was observing; the visual appeared as a reflection from the cornea of the subject's eye, (see Figure 2).

Interpretation of the Eye Movements.

The pictures of subject's eye movements were read by observing the position of the reflected image of the viewed scene with regard to the subject's pupil. To prepare these eye movement positions for computer analysis, however, required the numerical coding of these positions. The numbering system used (see Figure 4) was as follows:

1. Line Drawing Stimulus Fixation. This quadrant, numbered "1" will always contain a line drawing and

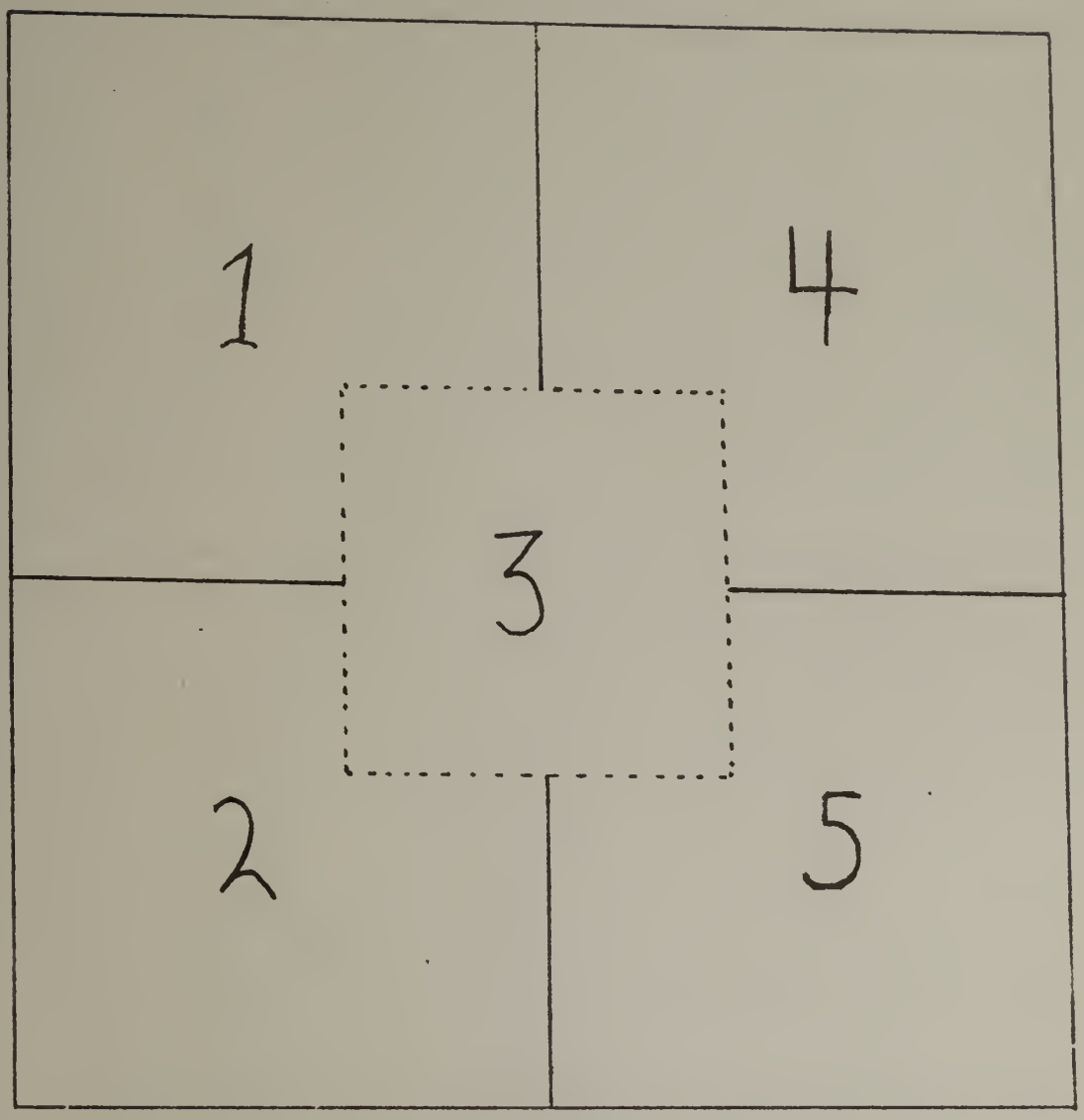


Figure 4. The Numbers Used to Code the Quadrants, Number 7 - Blinks, Number 8 = Offscreen

is known as the Line Drawing stimulus location. For half of the slides it was the upper left quadrant, for the other half it was the lower left quadrant.

2. Printed Word Stimulus Fixation. This quadrant, numbered "2", will always contain a printed word and is known as the Printed Word stimulus location. For half of the slides it was the lower left quadrant, for the other half it was the upper left quadrant.

3. Center Viewing Fixation. This area numbered "3" gives the location of a phantom central rectangle equal in size to a quadrant of the slide. No infor-ation was put into this position.

4. Printed Word Response Fixation. This quadrant, numbered "4" will always contain a printed word and is known as the Printed Word response location. It was always located diagonally opposite the Printed Word stimulus location.

5. Line Drawing Response Fixation. This quadrant, numbered "5" will always contain a line drawing and is known as the Line Drawing response location. It was always located diagonally opposite the Line Drawing stimulus location.

7. Eye Blink. A number "7" was recorded for each of the frames showing the eyelid in a blinking position,

thereby obscuring the direction of the subject's looking at that moment.

8. Off-Display Fixation. The number "8" was recorded for each frame where the eye fixation was located off the display.

Eye Movement Data.

Pictures of the subject's eye movements were taken during the subject's visual search for paired associate information. The Precriterion test and Postcriterion test eye movement pictures were evaluated to determine the subject's use of his eyes when scanning the simultaneously presented paired-associate visuals. The number and sequence of the fixations were determined from an analysis of the film record and served as the individual's raw eye movement data.

For the purposes of the present study the raw fixation information was not used directly. Eye fixation sequential processing data was derived from the raw data by computer program.

Test Responses.

Analysis of the audio tape indicated the subject's verbal responses to the tests given at the end of each treatment and were used to determine the subject's efficiency of learning from this type of presentation.

Visual Stimulus Presentation Mode Description.

During the eye movement tests the subject viewed two different arrangements of visuals (see Figures 5 and 6). The visual presentation mode was randomly varied between the line drawing in the lower stimulus position, and the line drawing in the upper stimulus position, to prevent the subject's expecting a line drawing, or a printed word, in a particular location for each new visual. Besides counteracting a subject's acclimation to a constant format, the use of this diagonal presentation style tended to neutralize the cultural left-to-right bias. No test, however, was used to evaluate the success of this procedure.

Search Pattern Variables.

The following variable names will all involve three sequential eye fixations, this name will be followed by the presentation mode identifier, upper representing the line drawing in upper stimulus position mode and lower representing the line drawing in the lower stimulus position mode. (See Figures 5 and 6).

Methodological Variables. The Methodological variables (variables numbered 2-13 and 38-49) are those search patterns designed to detect a pattern related to position rather than to stimulus material. A clockwise or counter-clockwise sequence of eye movements would be considered a methodological

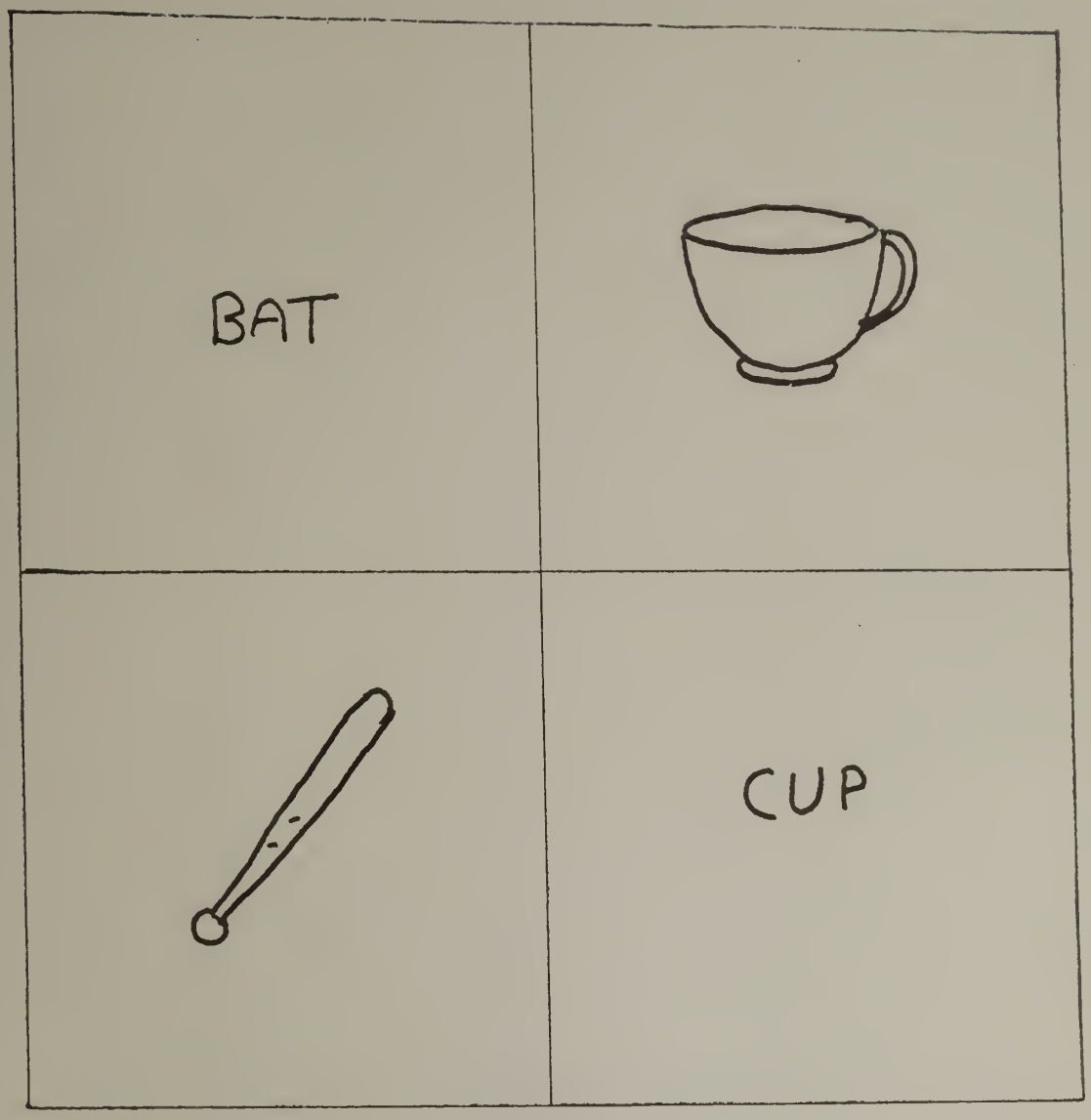


Figure 5. Line Drawing in the Lower Stimulus Position Presentation Mode

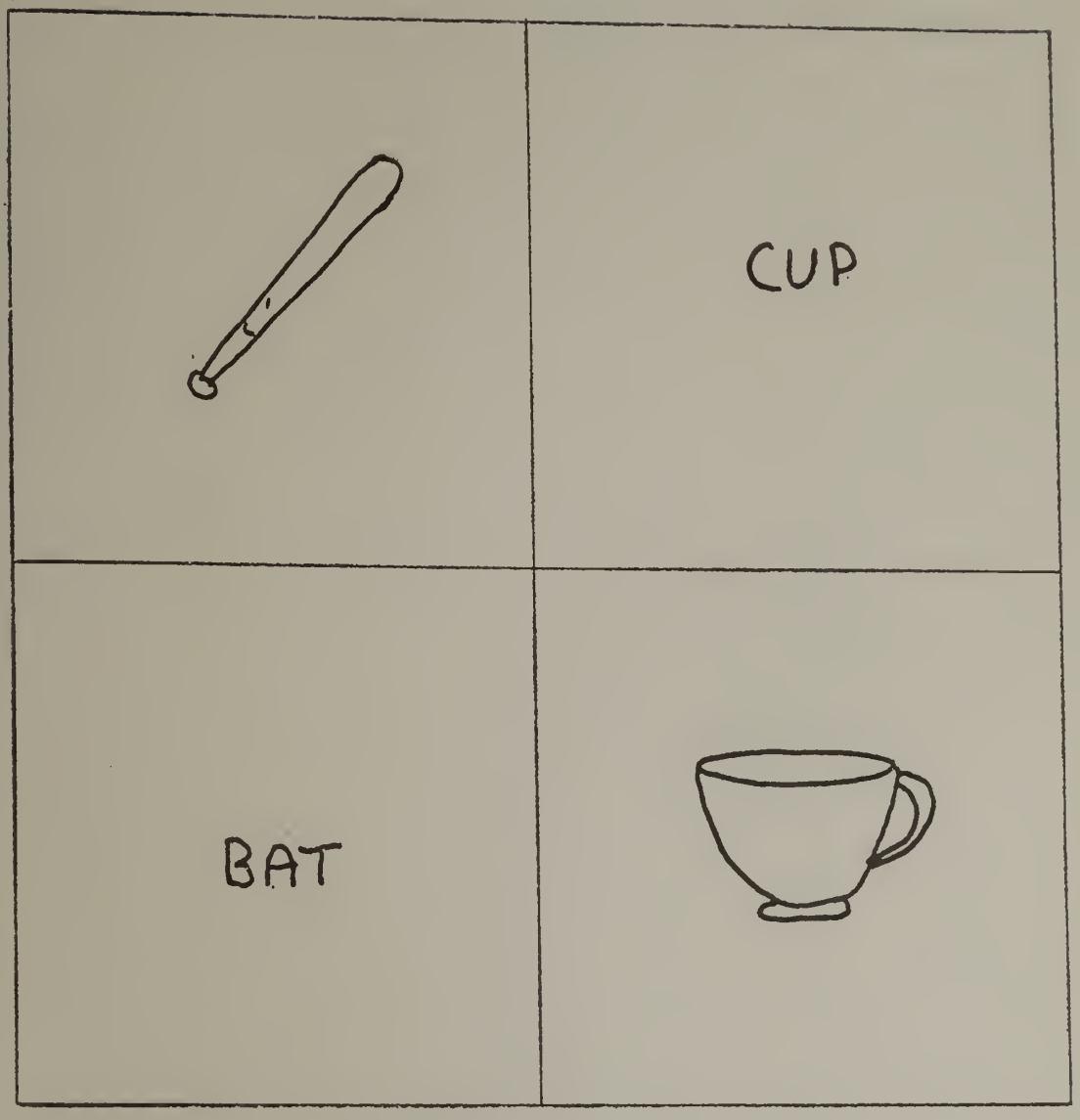
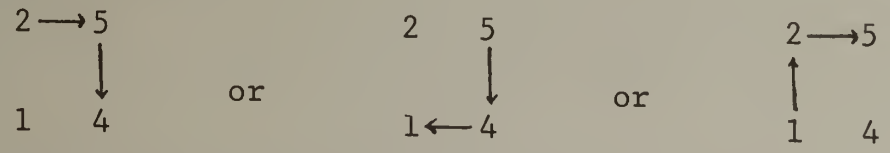


Figure 6. Line Drawing in the Upper Stimulus Position Presentation Mode

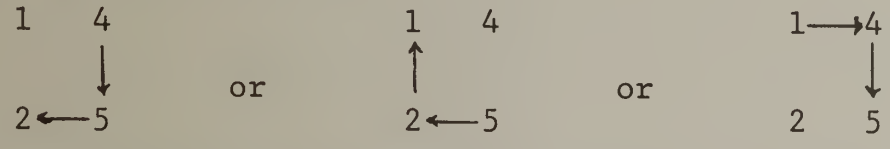
pattern. The methodological variables are described as follows:

VAR #2 - Clockwise, Lower. These variable counts represent the number of times the subject exhibited a Clockwise eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



etc. would qualify as Clockwise, Lower, eye fixation sequences.

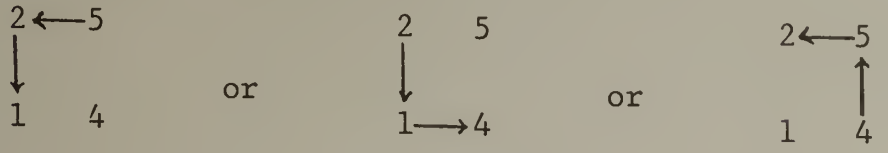
VAR #3 - Clockwise, Upper. These variable counts represent the number of times the subject exhibited a Clockwise eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:



etc. would qualify as Clockwise, Upper, eye fixation sequences.

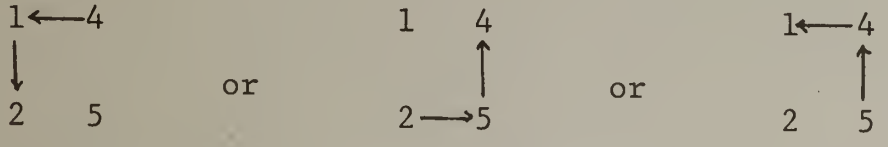
VAR #4 - Clockwise, Total. These variable counts represent the number of times the subject exhibited a Clockwise, Lower, eye fixation sequence plus the number of times the Clockwise, Upper, eye fixation sequence was employed.

VAR #5 - Counter-clockwise, Lower. These variable counts represent the number of times the subject exhibited a Counter-clockwise eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



etc. would qualify as Counter-clockwise, Lower, eye fixation sequences.

VAR #6 - Counter-clockwise, Upper. These variable counts represent the number of times the subject exhibited a Counter-clockwise eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:



etc. would qualify as Counter-clockwise, Upper, eye fixation sequences.

VAR #7 - Counter-clockwise, Total. These variable counts represent the number of times the subject exhibited the Counter-clockwise, Lower, eye fixation sequence plus the number of times the Counter-clockwise, Upper, eye fixation sequence was employed.

VAR #8 - Horizontal, Lower. These variable counts represent the number of times the subject exhibited a Horizontal eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:

$2 \rightleftharpoons 5$ $\quad$ $2 \quad 5$ $\quad$ $2 \rightleftharpoons 5$

$1 \quad 4$ or $1 \rightleftharpoons 4$ or $1 \quad 4$

etc. would qualify as Horizontal, Lower, eye fixation sequences.

VAR #9 - Horizontal, Upper. These variable counts represent the number of times the subject exhibited a Horizontal eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:

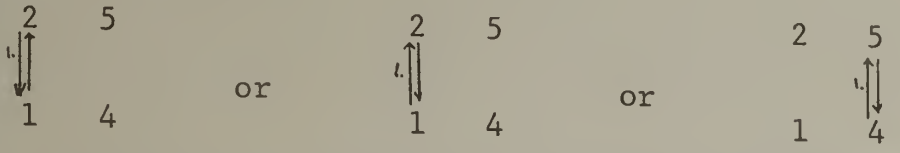
$1 \rightleftharpoons 4$ $\quad$ $1 \quad 4$ $\quad$ $1 \rightleftharpoons 4$

$2 \quad 5$ or $2 \rightleftharpoons 5$ or $2 \quad 5$

etc. would qualify as Horizontal, Upper, eye fixation sequences.

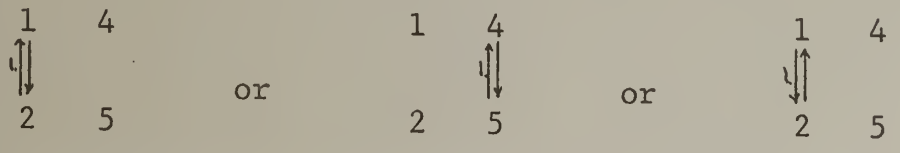
VAR #10 - Horizontal, Total. These variable counts represent the number of times the subject exhibited the Horizontal, Lower, eye fixation sequence plus the number of times the Horizontal, Upper, eye fixation sequence was employed.

VAR #11 - Vertical, Lower. These variable counts represent the number of times the subject exhibited a Vertical eye fixation sequence during his viewing of the line drawing in the lower stimulus position of presentation mode. Patterns such as:



etc. would qualify as Vertical, Lower, eye fixation sequences.

VAR #12 - Vertical, Upper. These variable counts represent the number of times the subject exhibited a Vertical eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:

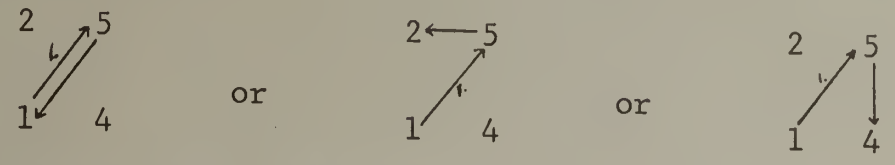


etc. would qualify as Vertical, Upper, eye fixation sequences.

VAR #13 - Vertical, Total. These variable counts represent the number of times the subject exhibited the Vertical, Lower, eye fixation sequence plus the number of times the Vertical, Upper, eye fixation sequence was employed.

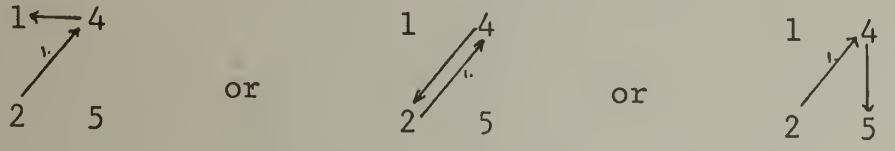
VAR #38 - Right Up Diagonal, Lower. These variable counts represent the number of times the subject exhibited a Right Up Diagonal eye fixation sequence during his viewing

of the line drawing in the lower stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 fixations must have been on that diagonal. Patterns such as:



etc. would qualify as Right Up Diagonal, Lower, eye fixation sequences.

VAR #39 - Right Up Diagonal, Upper. These variable counts represent the number of times the subject exhibited a Right Up Diagonal eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 eye fixations must have been on that diagonal. Patterns such as:

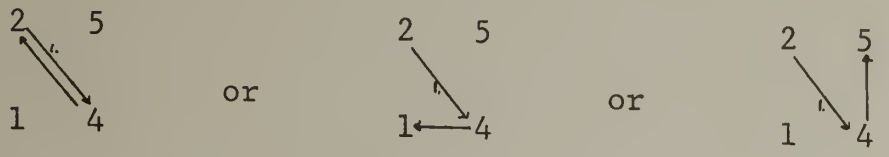


etc. would qualify as Right Up Diagonal, Upper, eye fixation sequences.

VAR #40 - Right Up Diagonal, Total. These variable counts represent the number of times the subject exhibited the Right Up Diagonal, Lower, search pattern sequence plus the number of times the Right Up Diagonal, Upper, search

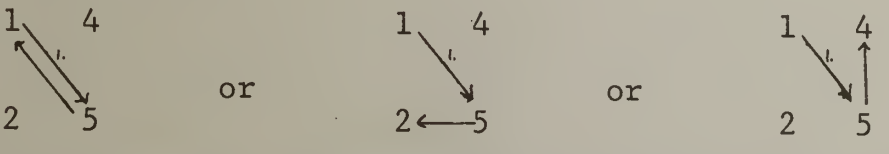
pattern sequence was employed.

VAR # 41 - Right Down Diagonal, Lower. These variable counts represent the number of times the subject exhibited a Right Down Diagonal eye fixation sequence during his viewing of the line drawing lower stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 eye fixations must have been on that diagonal. Patterns such as:



etc. would qualify as Right Down Diagonal, Lower, eye fixation sequences.

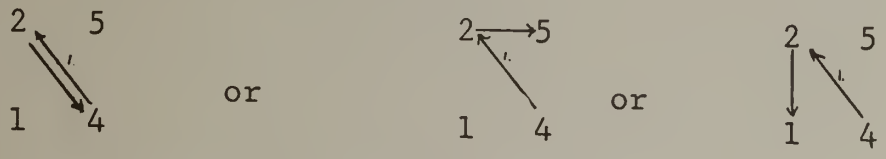
VAR #42 - Right Down Diagonal,Upper. These variable counts represent the number of times the subject exhibited a Right Down Diagonal eye fixation sequence during his viewing of the line drawing upper stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 eye fixations must have been on that diagonal. Patterns such as:



etc. would qualify as Right Down Diagonal,Upper, eye fixation sequences.

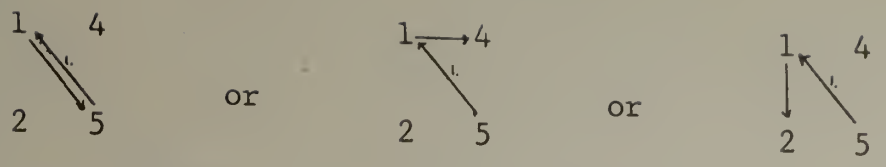
VAR #43 - Right Down Diagonal, Total. These variable counts represent the number of times the subject exhibited the Right Down Diagonal, Lower, search pattern sequence plus the number of times the Right Down Diagonal, Upper, search pattern sequence was employed.

VAR #44 - Left Up Diagonal, Lower. These variable counts represent the number of times the subject exhibited a Left Up Diagonal eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 eye fixations must have been on that diagonal. Patterns such as:



etc. would qualify as Left Up Diagonal, Lower, eye fixation sequences.

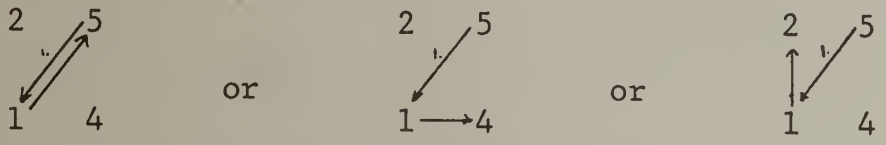
VAR #45 - Left Up Diagonal, Upper. These variable counts represent the number of times the subject exhibited a Left Up Diagonal eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 eye fixations must have been on that diagonal. Patterns such as:



etc. would qualify as Left Up Diagonal, Upper, eye fixation sequences.

VAR #46 - Left Up Diagonal, Total. These variable counts represent the number of times the subject exhibited the Left Up Diagonal, Lower, search pattern sequence plus the number of times the Left Up Diagonal, Upper, search pattern sequence was employed.

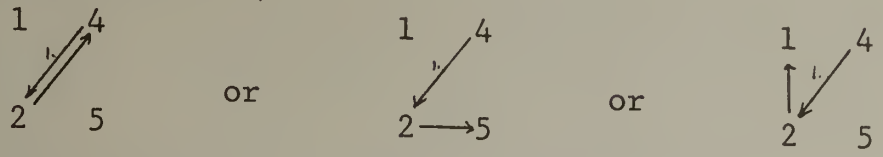
VAR #47 - Left Down Diagonal, Lower. These variable counts represent the number of times the subject exhibited a Left Down Diagonal eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 eye fixations must have been on that diagonal. Patterns such as:



etc. would qualify as Left Down Diagonal, Lower, eye fixation sequences.

VAR #48 - Left Down Diagonal, Upper. These variable counts represent the number of times the subject exhibited a Left Down Diagonal eye fixation sequence during his viewing

of the line drawing in the upper stimulus position presentation mode. In order to qualify as a diagonal eye movement, 2 out of 3 eye fixations must have been on that diagonal. Patterns such as:



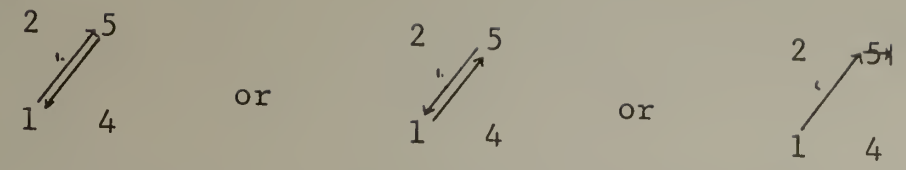
etc. would qualify as Left Down Diagonal, Upper, eye fixation sequences.

VAR #49 - Left Down Diagonal, Total. These variable counts represent the number of times the subject exhibited the Left Down Diagonal, Lower, search pattern sequence plus the number of times the Left Down Diagonal, Upper, search pattern sequence was employed.

Content Variables. The Content variables (variables numbered 14-37) are those variables designed to detect the subject's bias for stimulus material rather than a sequence of positions. A series of three eye fixations such as: a printed word, a printed word, and then another printed word, would constitute a content sequence pattern.

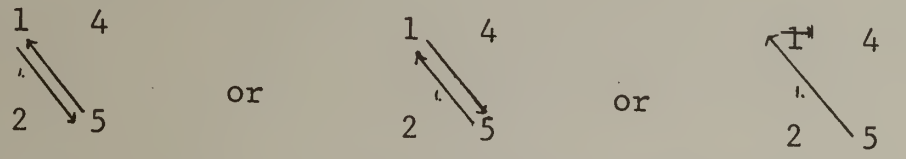
VAR #14 - Line Drawing, Line Drawing, Line Drawing, Lower. These variable counts represent the number of times the subject exhibited a Line Drawing, Line Drawing, Line Drawing, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns

such as:



etc. would qualify as Line Drawing, Line Drawing, Line Drawing, Lower, eye fixation sequences.

VAR #15 - Line Drawing, Line Drawing, Line Drawing, Upper. These variable counts represent the number of times the subject exhibited a Line Drawing, Line Drawing, Line Drawing, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:

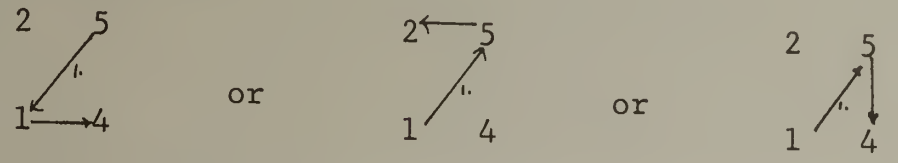


etc. would qualify as Line Drawing, Line Drawing, Line Drawing, Upper, eye fixation sequences.

VAR #16 - Line Drawing, Line Drawing, Line Drawing, Total. These variable counts represent the number of times the subject exhibited the Line Drawing, Line Drawing, Line Drawing, Lower, search pattern plus the number of times the Line Drawing, Line Drawing, Line Drawing, Upper, search pattern sequence was employed.

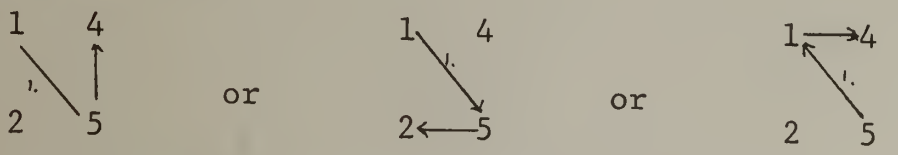
VAR #17 - Line Drawing, Line Drawing, Printed Word, Lower. These variable counts represent the number of times

the subject exhibited a Line Drawing, Line Drawing, Printed Word, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



etc. would qualify as Line Drawing, Line Drawing, Printed Word, Lower, eye fixation sequences.

VAR #18 - Line Drawing, Line Drawing, Printed Word, Upper. These variable counts represent the number of times the subject exhibited a Line Drawing, Line Drawing, Printed Word, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:

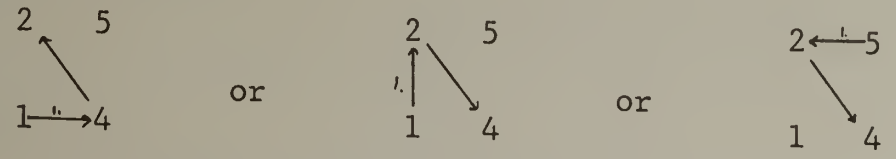


etc. would qualify as Line Drawing, Line Drawing, Printed Word, Upper, eye fixation sequences.

VAR #19 - Line Drawing, Line Drawing, Printed Word, Total. These variable counts represent the number of times the subject exhibited the Line Drawing, Line Drawing, Printed Word, Lower, pattern sequence plus the number of times the Line Drawing, Line Drawing, Printed Word, Upper, search

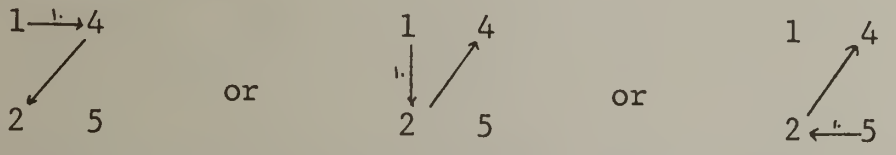
pattern sequence was employed.

VAR #20 - Line Drawing, Printed Word, Printed Word, Lower. These variable counts represent the number of times the subject exhibited a Line Drawing, Printed Word, Printed Word, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



etc. would qualify as Line Drawing, Printed Word, Printed Word, Lower, eye fixation sequences.

VAR #21 - Line Drawing, Printed Word, Printed Word, Upper. These variable counts represent the number of times the subject exhibited a Line Drawing, Printed Word, Printed Word, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:

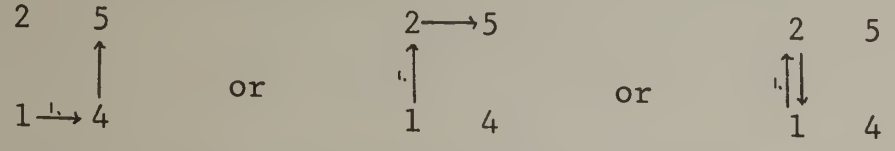


etc. would qualify as Line Drawing, Printed Word, Printed Word, Upper, eye fixation sequences.

VAR #22 - Line Drawing, Printed Word, Printed Word, Total. These variable counts represent the number of times

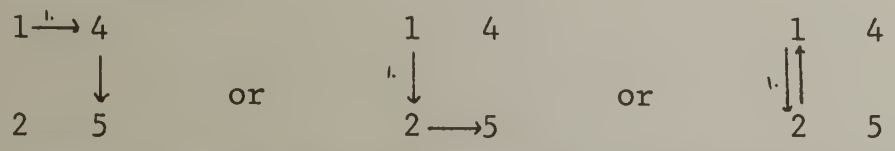
the subject exhibited the Line Drawing, Printed Word, Printed Word, Lower, search pattern sequence plus the number of times the Line Drawing, Printed Word, Printed Word, Upper, search pattern sequence was employed.

VAR #23 - Line Drawing, Printed Word, Line Drawing, Lower. These variable counts represent the number of times the subject exhibited a Line Drawing, Printed Word, Line Drawing, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



etc. would qualify as Line Drawing, Printed Word, Line Drawing, Lower, eye fixation sequences.

VAR #24 - Line Drawing, Printed Word, Line Drawing, Upper. These variable counts represent the number of times the subject exhibited a Line Drawing, Printed Word, Line Drawing, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:

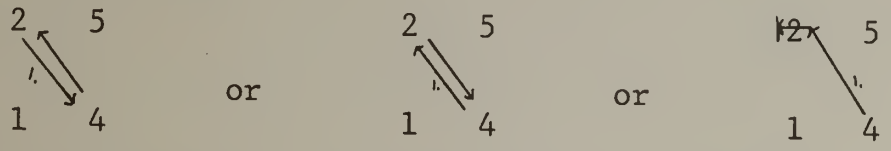


etc. would qualify as Line Drawing, Printed Word, Line

Drawing, Upper, eye fixation sequences.

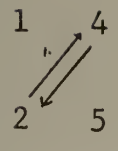
VAR #25 - Line Drawing, Printed Word, Line Drawing, Total. These variable counts represent the number of times the subject exhibited the Line Drawing, Printed Word, Line Drawing, Lower, search pattern sequence plus the number of times the Line Drawing, Printed Word, Line Drawing, Upper, search pattern was employed.

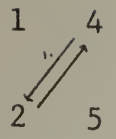
VAR #26 - Printed Word, Printed Word, Printed Word, Lower. These variable counts represent the number of times the subject exhibited a Printed Word, Printed Word, Printed Word, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:

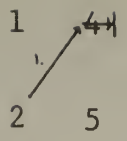


etc. would qualify as Printed Word, Printed Word, Printed Word, Lower, eye fixation sequences.

VAR #27 - Printed Word, Printed Word, Printed Word, Upper. These variable counts represent the number of times the subject exhibited a Printed Word, Printed Word, Printed Word, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:



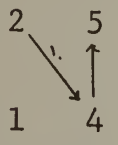
or


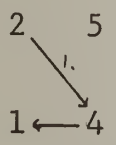
or


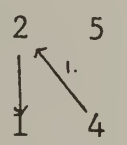
etc. would qualify as Printed Word, Printed Word, Printed Word, Upper, eye fixation sequences.

VAR #28 - Printed Word, Printed Word, Printed Word, Total. These variable counts represent the number of times the subject exhibited the Printed Word, Printed Word, Printed Word, Lower, search pattern sequence plus the number of times the Printed Word, Printed Word, Printed Word, Upper, search pattern sequence was employed.

VAR #29 - Printed Word, Printed Word, Line Drawing, Lower. These variable counts represent the number of times the subject exhibited a Printed Word, Printed Word, Line Drawing, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



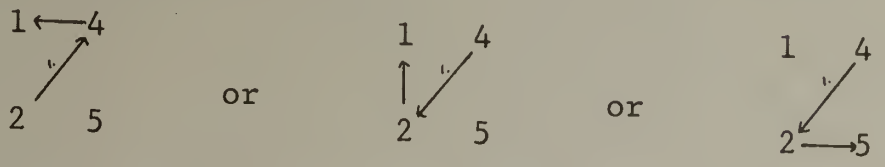
or


or


etc. would qualify as Printed Word, Printed Word, Line Drawing, Lower, eye fixation sequences.

VAR #30 - Printed Word, Printed Word, Line Drawing, Upper. These variable counts represent the number of times the subject exhibited a Printed Word, Printed Word, Line

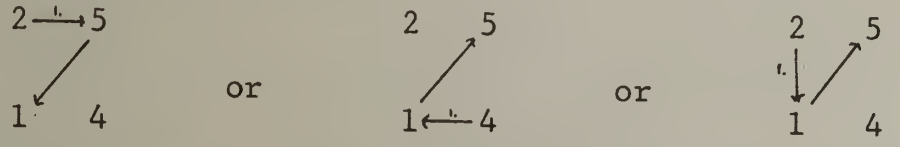
Drawing, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:



etc. would qualify as Printed Word, Printed Word, Line Drawing, Upper, eye fixation sequences.

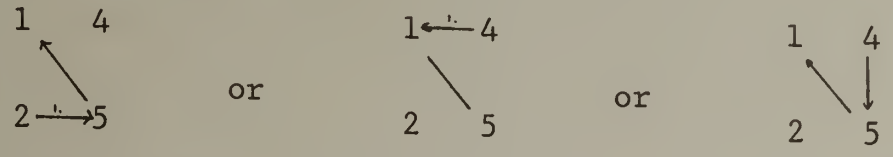
VAR #31 - Printed Word, Printed Word, Line Drawing, Total. These variable counts represent the number of times the subject exhibited the Printed Word, Printed Word, Line Drawing, Lower, search pattern sequence plus the number of times the Printed Word, Printed Word, Line Drawing, Upper, search pattern sequence was employed.

VAR #32 - Printed Word, Line Drawing, Line Drawing, Lower. These variable counts represent the number of times the subject exhibited a Printed Word, Line Drawing, Line Drawing, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



etc. would qualify as Printed Word, Line Drawing, Line Drawing, Lower, eye fixation sequences.

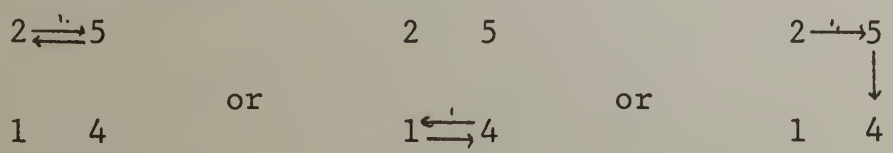
VAR #33 - Printed Word, Line Drawing, Line Drawing, Upper. These variable counts represent the number of times the subject exhibited a Printed Word, Line Drawing, Line Drawing, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:



etc. would qualify as Printed Word, Line Drawing, Line Drawing, Upper, eye fixation sequences.

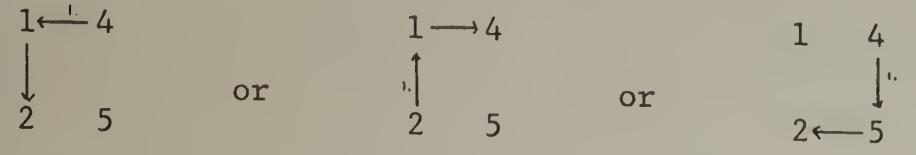
VAR #34 - Printed Word, Line Drawing, Line Drawing, Total. These variable counts represent the number of times the subject exhibited the Printed Word, Line Drawing, Line Drawing, Lower, search pattern sequence plus the number of times the Printed Word, Line Drawing, Line Drawing, Upper, search pattern sequence was employed.

VAR #35 - Printed Word, Line Drawing, Printed Word, Lower. These variable counts represent the number of times the subject exhibited a Printed Word, Line Drawing, Printed Word, eye fixation sequence during his viewing of the line drawing in the lower stimulus position presentation mode. Patterns such as:



etc. would qualify as Printed Word, Line Drawing, Printed Word, Lower, eye fixation sequences.

VAR #36 - Printed Word, Line Drawing, Printed Word, Upper. These variable counts represent the number of times the subject exhibited a Printed Word, Line Drawing, Printed Word, eye fixation sequence during his viewing of the line drawing in the upper stimulus position presentation mode. Patterns such as:



etc. would qualify as Printed Word, Line Drawing, Printed Word, Upper, eye fixation sequences.

VAR #37 - Printed Word, Line Drawing, Printed Word, Total. These variable counts represent the number of times the subject exhibited the Printed Word, Line Drawing, Printed Word, Lower, search pattern sequence plus the number of times the Printed Word, Line Drawing, Printed Word, Upper, search pattern sequence was employed.

Treatment of Variables.

This array of processor variables, for seventh and eighth grades were then computer analyzed to determine in what manner, and to what degree, the students differed from one another and how they were similar.

Attempts were made through correlation and regression analysis to determine if the type of idiosyncracy represented by the individual, and/or the group, constituted any basis for prediction of success with the Ability variables.

The same procedure was followed for the tenth and eleventh grade cell, after which an intercell study was instituted to determine the differences and similarities, between the two groups, regarding numbers and types of individualistic eye movement patterns and whether the same correlation patterns existed across the two groups.

Subpopulations.

For the seventh and eighth grade and the tenth and eleventh grade populations there were established Changer and Nonchanger subpopulations. (See page 3).

Summary of Main Variables

Methodological Variables:

2. Clockwise, Lower
3. Clockwise, Upper
4. Clockwise, Total
5. Counter-clockwise, Lower
6. Counter-clockwise, Upper
7. Counter-clockwise, Total
8. Horizontal, Lower
9. Horizontal, Upper
10. Horizontal, Total
11. Vertical, Lower
12. Vertical, Upper
13. Vertical, Total
38. Right Up Diagonal, Lower
39. Right Up Diagonal, Upper
40. Right Up Diagonal, Total
41. Right Down Diagonal, Lower
42. Right Down Diagonal, Upper
43. Right Down Diagonal, Total
44. Left Up Diagonal, Lower
45. Left Up Diagonal, Upper
46. Left Up Diagonal, Total
47. Left Down Diagonal, Lower
48. Left Down Diagonal, Upper
49. Left Down Diagonal, Total

Content Variables:

14. Line Drawing, Line Drawing, Line Drawing; Lower
15. Line Drawing, Line Drawing, Line Drawing; Upper
16. Line Drawing, Line Drawing, Line Drawing; Total
17. Line Drawing, Line Drawing, Printed Word; Lower
18. Line Drawing, Line Drawing, Printed Word; Upper
19. Line Drawing, Line Drawing, Printed Word; Total
20. Line Drawing, Printed Word, Printed Word; Lower
21. Line Drawing, Printed Word, Printed Word; Upper
22. Line Drawing, Printed Word, Printed Word; Total
23. Line Drawing, Printed Word, Line Drawing; Lower
24. Line Drawing, Printed Word, Line Drawing; Upper
25. Line Drawing, Printed Word, Line Drawing; Total
26. Printed Word, Printed Word, Printed Word; Lower
27. Printed Word, Printed Word, Printed Word; Upper
28. Printed Word, Printed Word, Printed Word; Total

29. Printed Word, Printed Word, Line Drawing; Lower
30. Printed Word, Printed Word, Line Drawing; Upper
31. Printed Word, Printed Word, Line Drawing; Total
32. Printed Word, Line Drawing, Line Drawing; Lower
33. Printed Word, Line Drawing, Line Drawing; Upper
34. Printed Word, Line Drawing, Line Drawing; Total
35. Printed Word, Line Drawing, Printed Word; Lower
36. Printed Word, Line Drawing, Printed Word; Upper
37. Printed Word, Line Drawing, Printed Word; Total

Ability Variables:

72. Verbal Score-Differential Aptitude Test (D.A.T.)
73. Numerical (D.A.T.)
74. Verbal and Numerical (D.A.T.)
75. Abstract Reasoning (D.A.T.)
76. Clerical Speed and Accuracy (D.A.T.)
77. Mechanical Reasoning (D.A.T.)
78. Spatial Relationships (D.A.T.)
79. Spelling (D.A.T.)
80. Grammar (D.A.T.)
81. Reading Percent-Science Research Associates (S.R.A.)
82. Reading Grade Equivalent (S.R.A.)
83. Math Percent (S.R.A.)
84. Math Grade Equivalent (S.R.A.)
85. Identical Pictures Part A-French Aptitude Test (E.T.S.)
86. Identical Pictures Part B (E.T.S.)
87. Maze Tracing Speed Test Part A (E.T.S.)
88. Maze Tracing Speed Test Part B (E.T.S.)
89. Surface Development Part A (E.T.S.)
90. Surface Development Part B (E.T.S.)
91. Hidden Figures Part A (E.T.S.)
92. Hidden Figures Part B (E.T.S.)
93. Letter Span Auditory Test (E.T.S.)
94. Extended Range Vocabulary Part A (E.T.S.)
95. Extended Range Vocabulary Part B (E.T.S.)
96. Paired Associate Precriterion
99. Paired Associate Postcriterion

Criterion Variables:

97. Printed Word Criterion Test
98. Line Drawing Criterion Test

CHAPTER IV

RESULTS

The population was divided into several subdivisions for analysis purposes. Eye movement search patterns of each subdivision, and composites of subdivisions, were examined regarding their relationship with the results of the E.T.S. (French) battery of tests, S.R.A. subscores, D.A.T. subscores and the learning efficiency scores, using Pearson's correlations, parallelism of regression and T tests.

Hypothesis IA

Seventh and Eighth Grade Analysis

This hypothesis states that: eye movement search patterns for the seventh and eighth grade population will correlate with selected Ability variables. Tables 1-4 represent Pearson correlations for the Changer/Nonchanger subpopulations, and Methodological variables and Content variables versus the Ability variables.

Total Population.

The total population data analysis empirically supports this hypothesis for future studies, with similar populations, due to 197 (22 percent) significant correlations with the Ability variables, as exhibited in Tables 1-4. Only those

correlations of $p < .05$ are shown, those correlations of $p < .01$ are underlined.

Nonchanger Subpopulation.

Methodological Variables. The Methodological variables (2-13 and 38-49, Table 1) show a maximum correlation of $r = .42$ for variable 49 (Left Down Diagonal, Total) with variable 95 (Extended Range Vocabulary Part B).

There were a total of 57 (13 percent) significant correlations for this group, of which 35 were significant at $p < .05$, and 22 were significant at the $p < .01$ level.

Content Variables. The Content variables (14-37, Table 2) show a maximum correlation of $r = .38$ for variable 22 (Line Drawing, Printed Word, Printed Word; Total) with variable 89 (Surface Development Part A).

There were a total of 43 (9 percent) significant correlations, of which 23 were significant at the $p < .05$ level, and 20 were significant at the $p < .01$ level.

Changer Subpopulation.

Methodological Variables. The Methodological variables (2-13 and 38-49, Table 3) show a maximum correlation of $r = .27$ for variable 40 (Right Up Diagonal, Total) with variable 96 (Paired Associate Precriterion Test).

There were a total of 57 significant correlations, of which 31 (13 percent) were significant at the $p < .05$ level, and 26 were significant at the $p < .01$ level.

Content Variables. The Content variables (14-37,

TABLE I

PEARSON CORRELATIONS FOR SEVENTH AND EIGHTH GRADE NONCHANGER SUBPOPULATION OF METHODOLOGICAL VARIABLES WITH ABILITY VARIABLES

Methodological Variables	Ability Variables																		
	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
2	.	.	.	.	.	29	.	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	-27	-26	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.	.	-33	.	.	-28	.	.
9	28	.	30	27	.	.	.	.	.	.	-38	.	.	.	32	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	-30	.	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12	-33	-29	-38	-39	.	.	.	.	.	.	.	.	.	.	-35	.	.	.	.
13	-27	.	-35	-31	.	.	-26	.	.	.	.	.	.	.	-30	.	.	.	.
38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
39	.	.	.	.	-31	.	.	.	.	.	35	.	.	.	.	.	.	.	.
40	.	.	.	.	-29	.	.	.	.	.	31	.	.	.	.	.	.	.	.
41	.	.	.	.	.	.	.	.	.	.	.	38	.	.	.	.	.	.	.
42	.	.	.	.	27	34	.	.	.	.	.	.	.	.	.	.	-25	.	.
43	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44	.	.	.	.	.	-29	.	.	.	.	.	.	.	.	.	.	.	.	.
45	.	.	.	.	.	.	.	27	.	.	.	.	.	.	.	.	.	.	.
46	.	.	.	.	-29	.	.	.	.	.	.	.	.	.	.	.	.	.	.
47	29	28	.	.	-30	.	.	.	.	.	37	-29	.	.	28	.	-29	.	.
48	32	32	36	38	.	.	.	30	33	.	.	.	.	32	34	.	.	.	.
49	41	40	29	34	-34	-28	.	36	29	.	.	.	.	28	42	.	.	.	.

TABLE 2

PEARSON CORRELATIONS FOR SEVENTH AND EIGHTH GRADE NONCHANGER SUBPOPULATION OF CONTENT VARIABLES WITH ABILITY VARIABLES

Content Variables	Ability Variables																	
	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
14	.32	.32	.	.	-.26	.	.	.	.34	.	.31	-.30	.	.	.26	.	.	.	.
15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16	.	.	.	.	.	.	.	.	.36	.	.36	.27	.	.	.	.	.	.	.
17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18	.	.	-.34	-.31	.	.	-.34	-.43	.	-.29	.	.	.	.	.	.	.	-.30	.
19	.	.	-.29	-.26	.	.	.	.	.	.	.	-.28	.	.	.	.	.	-.33	.
20	-.26	.	-.34	-.34	.	.	.	.	-.37	-.30	.	.	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-.36	.	.	.
22	.	.	.	.	.	.	.	.	-.38	-.29	.	.	.	-.28	.	.	.	.	-.29
23	.	.	.	.	.	.	.	.	.	.	.	.	.	.27	.	.	.	.	.
24	.	.	.	.	.	.	.	.	.	.	.	-.37	.	.	.	.	.	.	.
25	.	.	.	.	.	.	.	.	.	.	.	-.29	.	.	.	.	.	.	.
26	-.31	-.34	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
27	.	.	.	.	.	.	.	.	.	.	.	.29	.	.	.	.	.	.	.
28	.	.	.	.	.	.	.	.	.	.	.	.37	.	.	.	.	.	.	.
29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
31	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-.25	.	.
33	.	.	.	.	.	.	.	.	.	.	.	-.35	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.	.	.	.	.	-.32	.	.	.	.	.	.	.
35	-.36	-.30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
36	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
37	.28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

TABLE 3

PEARSON CORRELATIONS FOR SEVENTH AND EIGHTH GRADE CHANGER SUBPOPULATION OF METHODOLOGICAL VARIABLES WITH ABILITY VARIABLES

Methodological Variables	Ability Variables																	
	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
2																-17			
3						-15					-19								
4																-17		-17	
5																	-15		
6										-16									
7																	-15		
8											-16								
9																			
10						-17													
11							16						23			-19			-15
12																			
13													20			-17			-18
38																17	17		
39			16													23	19	22	24
40							-15									27	24	21	23
41			23	17															
42																	19		
43																	22		
44				15-16-19											16				
45																			
46																			
47				16-20-18-20									-20			22	24		22
48				-15		-16					15								
49				-24-20-25-25-17									-19			19	17		15

Table 4) show a maximum correlation of r = .26 for variable 23 (Line Drawing, Printed Word, Line Drawing ; Lower) with variable 91 (Hidden Figures Part A).

There were a total of 30 (7 percent) significant correlations, of which 11 were significant at the $p < .05$ level, and 9 were significant at the $p < .01$ level.

Hypothesis IB

Tenth and Eleventh Grade Analysis

This hypothesis states that: eye movement search patterns for the tenth and eleventh grade population will correlate with selected Ability variables. Tables 5-8 represent Pearson Correlations for the Changer/Nonchanger subpopulation, and Methodological variables and Content variables versus the Ability variables (72-80 and 85-99).

Total Population.

The total population data analysis empirically supports this hypothesis for future studies with similar populations, due to 192 (21 percent) significant correlations exhibited in Tables 5-8. Only those correlations of $p < .05$ are shown, those correlations of $p < .01$ are underlined.

Nonchanger Subpopulations.

Methodological Variables. The Methodological variables (2-13 and 38-49, Table 5) show a maximum correlation of

TABLE 4

PEARSON CORRELATIONS FOR SEVENTH AND EIGHTH GRADE CHANGER SUBPOPULATION OF CONTENT VARIABLES WITH ABILITY VARIABLES

Content Variables	Ability Variables																		
	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
14	.	.	.	17	-16	.	-21	.	.	.	.	.	-18	.	.	24	24	.	19
15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	.	.
16	.	.	.	.	.	.	-19	.	.	.	.	.	-18	.	.	16	25	.	.
17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18	.	.	.	.	.	.	.	.	.	.	-16	.	.	.	.	.	.	-22	.
19	.	.	.	.	.	.	.	.	.	-18	.	.	.	.	.	.	.	-20	-16
20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21	.	.	.	.	.	-20	.	.	.	.	.	.	.	.	.	.	.	.	.
22	.	.	.	.	.	-19	.	.	.	.	.	.	.	.	.	.	.	.	.
23	.	.	.	.	.	.	.	.	.	.	26	.	.	.	.	.	.	.	.
24	.	.	.	.	.	.	.	.	.	.	.	-19	.	.	.	.	.	.	.
25	.	.	.	.	.	.	.	.	.	.	19	-16	.	.	.	.	.	.	.
26	.	.	.	.	.	17	.	.	.	.	.	.	.	.	.	.	.	.	.
27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
31	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
33	.	.	.	.	.	.	-15	.	.	.	.	.	.	.	.	.	.	.	.
34	.	.	.	.	.	.	-17	-15	.	.	.	.	.	.	.	.	.	.	.
35	.	.	-16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
36	.	.	.	.	.	-19	.	.	.	.	.	.	.	.	.	.	.	.	.
37	.	.	.	.	.	.	.	.	.	.	16	.	.	.	.	.	.	.	.

TABLE 5

PEARSON CORRELATIONS FOR TENTH AND ELEVENTH GRADE NONCHANGER SUBPOPULATION OF METHODOLOGICAL VARIABLES WITH ABILITY VARIABLES

Methodological Variables	Ability Variables																						
	72	73	74	75	76	77	78	79	80	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.	.	.	.	-26	.	.	.	.	28	.	20	.	.	.	.	.	.
4	.	.	.	.	.	.	.	.	.	.	-26	.	.	.	.	25	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24	27	.	25	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-25	.	.	-21
7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	29	.	.	-21	.	.	-27
8	.	.	.	.	.	.	.	.	.	.	-29	.	.	31	25	.	.	21	.	.	.	.	.	.
9	23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.	.	.	-29	.	.	25	21	.	.	27	.	.	.	.	.	.
11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.	.	.	.	-21	.	.	.	.	22	.	.	.	.	-23	.	.	-20
13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	29	.	.	.	-21	-20	.	.	.
38	.	.	.	.	.	.	.	.	.	.	.	.	.	-21	-27	.	.	.	.	.	.	.	.	.
39	.	.	.	.	27	-26	-26	.	.	.	.	.	.	.	.	.	.	..	.	.	22	.	.	.
40	.	.	.	.	20	.	-29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
41	.	.	.	.	.	-21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
42	-25	.	.	.	-26	27	.	.	.	.	20	.	-26	.	-20	.	.	-33	.	.	.	.	.	34
43	.	.	.	.	-22	.	.	.	.	.	.	.	-28	.	.	.	.	.	.	.	.	.	.	23
44	25	.	.	.	.	.	.	.	.	.	.	.	.	27	.	.	.	.	.	.	.	.	.	.
45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46	23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
47	.	.	.	-22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48	-25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49	-23	.	.	-29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

r = .34 for variable 42 (Right Down Diagonal, Upper) with variable 99 (Paired Associate Postcriterion Test).

Table 5 indicates a total of 60 (11 percent) significant correlations, of which 34 were significant at the $p < .05$ level, and 26 were significant at the $p < .01$ level.

Content Variables. The Content variables (14-37, Table 6) show a maximum correlation of r = .39 for variable 20 (Line Drawing, Printed Word, Printed Word; Lower) and variable 22 (Line Drawing, Printed Word, Printed Word; Total)with variable 91 (Hidden Figures Part A).

Table 6 indicates a total of 83 (15 percent) significant correlations, of which 51 were significant at the $p < .05$ level, and 32 were significant at the $p < .01$ level. Changer Subpopulation.

Methodological Variables. The Methodological variables (2-13 and 38-49, Table 7) show a maximum correlation of r = .30 for variable 38 (Right Up Diagonal, Lower) with variable 90 (Surface Development Part B).

Table 7 indicates a total of 19 (4 percent) significant correlations, of which 15 (3 percent) were significant at the $p < .05$ level, and 4 (1 percent) were significant at the $p < .01$ level.

Content Variables. The Content variables (14-37, Table 8) show a maximum correlation of r = .27 for variable

TABLE 6

PEARSON CORRELATIONS FOR TENTH AND ELEVENTH GRADE NONCHANGER SUBPOPULATION OF CONTENT VARIABLES WITH ABILITY VARIABLES

Content Variables	Ability Variables																								
	72	73	74	75	76	77	78	79	80	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
14	.	.	.	-20	.	.	.	.	.	.	.	.	-21	-23	-25	.	.	-24	.	.	.	.	.	24
15	.	.	.	.	.	.	.	.	.	.	.	.	-22	.	-23	.	.	-24	.	.	.	.	.	33
16	.	.	.	.	.	.	.	.	.	.	.	.	-25	-20	-27	.	.	-27	.	.	.	.	.	33
17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24	.	.	.	-25	.	.	.	.
18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22	23	.	.	.	.	.	.	.
19	.	.	.	.	.	.	21	.	.	.	-22	.	.	.	.	31	.	22	.	-25	.	.	.	.
20	.	.	.	.	.	-21	.	.	.	.	-26	.	.	.	20	39	21	26	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-26
22	.	.	.	.	.	-22	.	.	.	.	-29	.	.	.	.	39	.	28	.	.	.	.	.	.
23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-22	.	21	.	.
24	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
25	.	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-21	.	21	.	.
26	26	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	22	.	.	.	.	-24
27	.	.	.	.	.	.	.	.	.	.	.	.	.	24	28	.	.	.	.	.	31	.	.	.
28	.	.	.	.	.	.	.	.	.	.	.	.	.	28	34	.	.	.	.	.	27	.	.	-25
29	.	.	.	.	.	.	.	.	-20	.	.	20	31	.	.	31	.	23	.	.	.	.	.	.
30	.	.	.	.	.	-22	.	.	.	.	-26	.	23	.	.	23	.	30	.	.	-27	.	.	-26
31	.	.	.	.	.	.	.	.	.	.	.	.	33	.	.	31	.	32	.	.	.	.	.	-23
32	.	22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	27	.	-21	.	.	.	.
33	.	.	.	.	.	-25	.	.	-22	-29	.	.	.	.	.	.	.	20	.	.	.	.	.	.
34	.	23	.	.	.	.	.	.	.	-26	.	.	.	.	.	.	.	30	.	.	.	.	.	.
35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	26	.	.	.	.	.	.	.
36	.	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	20	.	.	.	.	.	.	.

TABLE 7

PEARSON CORRELATIONS FOR TENTH AND ELEVENTH GRADE CHANGER SUBPOPULATION OF METHODOLOGICAL VARIABLES WITH ABILITY VARIABLES

Methodological Variables	Ability Variables																						
	72	73	74	75	76	77	78	79	80	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
2																28								
3																								
4																								
5																								
6																								
7																								
8																23					-22			-22
9																								
10																23								-27
11																								22
12																								
13																								25
38	24								23							-30	-24							
39																								
40													-22			-27								
41											21													
42										-24	-25													
43																								
44																								
45																								
46																								
47																								
48							-21																	
49													-23											

32 (Printed Word, Line Drawing, Line Drawing, Lower) with variable 73 (Verbal Score, D.A.T. test). Variable 37 (Printed Word, Line Drawing, Printed Word, Total) also correlated at r = .27, but with two variables; i.e., variable 90 (Surface Development Part B) and variable 94 (Extended Range Vocabulary Part A).

Table 8 indicates a total of 31 (5 percent) significant correlations, of which 28 were significant at the $p < .05$ level, and 3 were significant at the $p < .01$ level.

Hypothesis IIA

This hypothesis states that: the seventh and eighth grade eye movement search pattern scores for the first two seconds of viewing, of each four-second visual display, will vary significantly from those of the last two seconds of viewing, for the Precriterion and the Postcriterion tests.

T tests were applied to the data from the first two seconds of viewing, versus the last two seconds of viewing, of each four-second visual display, to determine differences between them. Comparisons were also made between the first two seconds of Precriterion tests versus the first two seconds of the Postcriterion tests.

Tables 9-14 were derived from the seventh and eighth grade eye movement search pattern data. All of the Methodo-

TABLE 8

PEARSON CORRELATIONS FOR TENTH AND ELEVENTH GRADE CHANGER SUBPOPULATION OF CONTENT VARIABLES WITH ABILITY VARIABLES

Content Variables	Ability Variables																							
	72	73	74	75	76	77	78	79	80	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
14	.	.	.	.	.	.	.	.	23	.	.	.	-22	.	.	-25	.	.	.	.	.	.	.	.
15	.	.	.	.	.	.	.	.	.	-24	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16	.	.	.	.	.	.	.	.	.	-21	.	.	-23	.	.	-22	-25	.	.	.	.	.	.	28
17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-22	.	.	.	.	.	.
18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.
19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
24	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
25	.	.	.	.	-21	.	.	.	.	.	.	.	.	.	.	-21	.	.	.	.	.	.	.	.
26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26	.	.	.	.	.	.
27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-23	.	.	.	.	.	.	.	-24	.
28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-21	.
29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
31	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
32	.	27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
33	.	.	.	.	22	.	.	22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.	21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.	.	23	.
36	.	.	20	.	.	.	.	.	.	20	.	.	.	.	21	.	.	.	-25	.	.	.	.	.
37	.	.	.	.	.	.	.	.	.	23	.	.	.	.	27	.	.	.	-27	.	.	.	.	21

logical variables and Content variables (variables 2-53) were entered in an effort to detect variations in search patterns over time.

Total Population.

The total population data analysis empirically supports this hypothesis for future studies, with similar populations, due to 58 (29 percent) significant differences detected between the first two seconds of viewing and the last two seconds of viewing of the Precriterion and Postcriterion tests.

Changer Subpopulation.

The Changer subpopulation data analysis empirically supports this hypothesis for future studies due to 33 (34 percent) significant differences detected between the first two seconds of viewing, of each four-second display, and the last two seconds of viewing. (See Tables 9 and 11).

T tests between the first two seconds of the Changer Precriterion variable scores and the final two seconds of the Changer Precriterion variables scores (Table 9), indicate significant differences between these two groups for 17 variables (40 percent).

T tests between the first two seconds of the Changer Postcriterion variable scores and the final two seconds of the Changer Postcriterion variable scores (Table 11), indicate significant differences between these two groups for 16 variables (31 percent).

TABLE 9

T TESTS OF SEVENTH AND EIGHTH GRADE PRECRITERION CHANGER SUBPOPULATION FIRST 2 SECONDS VERSUS SECOND 2 SECONDS

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Clock.	5.29	2.73	.42	1.72	.091	4.02
2nd	Low.	8.12	3.57	.55			
1st	Clock.	10.65	3.74	.58	1.87	.051	3.22
2nd	Total	13.85	5.12	.80			
1st	Vert.	5.73	3.16	.49	1.13	.702	2.59
2nd	Low.	7.48	2.97	.46			
1st	Vert.	10.87	4.52	.70	1.00	.997	2.49
2nd	Total	13.36	4.53	.70			
1st	L.D.,Wd.	.51	.63	.10	3.51	.000	3.35
2nd	L.D.Low.	1.21	1.19	.18			
1st	L.D.,Wd.	1.29	1.12	.17	2.12	.020	2.36
2nd	Ld.,Tot.	2.02	1.63	.25			
1st	Wd.,Wd.	2.43	1.30	.20	1.23	.510	4.45
2nd	L.D.,Low.	3.65	1.17	.18			
1st	Wd.,Wd.	5.02	1.65	.25	1.06	.855	4.35
2nd	L.D.,Tot.	6.63	1.69	.26			
1st	Wd.,L.D.	2.48	1.07	.16	1.09	.776	4.31
2nd	L.D.Low.	3.48	1.02	.16			
1st	Wd.,L.D.	5.17	1.48	.23	1.08	.818	2.88
2nd	L.D. Tot.	6.09	1.42	.22			
1st	Wd.,L.D.	.70	.78	.12	3.08	.001	2.67
2nd	Wd.,Low.	1.36	1.37	.21			
1st	Wd.,L.D.	.70	.98	.15	1.08	.806	1.77
2nd	Wd.Upper	1.09	1.02	.15			
1st	Wd.,L.D.	1.41	1.36	.21	1.63	.129	3.05
2nd	Wd.Tot.	2.46	1.73	.27			

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 9--Continued

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Upper Rt.	1.19	1.64	.25			
2nd	Up Diag.	2.48	1.84	.28	1.26	.474	3.35
1st	Rt.Up Diag.	2.31	2.15	.33			
2nd	Total	3.97	2.85	.44	1.77	.075	2.97
1st	Upper Lt.	2.17	1.87	.29			
2nd	Up Diag.	1.29	1.55	.24	1.45	.245	2.31
1st	Lt.Up Diag.	3.70	2.66	.41			
2nd	Total	2.29	2.41	.37	1.22	.526	2.52

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 10

T TESTS OF SEVENTH AND EIGHTH GRADE PRECRITERION NONCHANGER SUBPOPULATION FIRST 2 SECONDS VERSUS SECOND 2 SECONDS

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Vert.	4.85	3.39	.90	1.15	.799	2.58
2nd	Low.	8.28	3.64	.97			
1st	Vert.	10.35	5.06	1.35	1.25	.692	1.94
2nd	Total	14.28	5.66	1.51			
1st	L.D.,L.D.	3.28	1.06	.28	1.17	.778	2.04
2nd	Wd. Low.	2.42	1.15	.30			
1st	L.D.,L.D.	6.35	1.33	.35	1.90	.262	2.23
2nd	Wd.,Tot.	5.00	1.84	.49			
1st	L.D.,Wd.	2.64	.74	.19	2.14	.184	2.23
2nd	Wd.,Upper	3.42	1.08	.29			
1st	Wd.,Wd.	2.35	1.59	.42	1.59	.416	2.88
2nd	L.D.,Low.	3.92	1.26	.33			
1st	Wd.,Wd.	1.92	1.32	.35	1.99	.227	3.61
2nd	L.D.Upper	3.50	.94	.25			
1st	Wd.,Wd.	4.28	2.40	.64	2.11	.191	4.04
2nd	L.D.Tot.	7.42	1.65	.44			
1st	Wd.,L.D.	.42	.93	.25	1.78	.311	3.25
2nd	Wd.Upper	1.78	1.25	.33			
1st	Wd.,L.D.	1.28	1.43	.38	1.68	.360	3.29
2nd	Wd. Tot.	3.35	1.86	.49			
1st	Rt. Up	.78	.97	.26	4.79	.008	2.51
2nd	Diag.Upper	2.35	2.13	.57			
1st	Rt. Up	1.57	1.60	.42	4.29	.013	2.03
2nd	Diag.Tot.	3.57	1.32	.88			
1st	Rt. Down	1.14	1.56	.41	1.67	.369	2.31
2nd	Diag.Low.	2.71	2.01	.53			

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 10--Continued

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Rt. Down	3.14	2.31	.61			
2nd	Diag.Tot.	4.78	2.57	.68	1.24	.705	1.77

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

Nonchanger Subpopulation.

The Nonchanger subpopulation data analysis empirically supports this hypothesis for future study due to 25 (26 percent) significant differences detected between the first two seconds of viewing, of each four-second display, and the last two seconds of viewing. (See Tables 10 and 12).

T tests between the first two seconds of the Nonchanger Precriterion variable scores and the last two seconds of the Nonchanger Precriterion variable scores (Table 10) indicate significant differences between these two groups for 14 variables (29 percent).

T tests between the first two seconds of the Nonchanger Postcriterion test variable scores and the final two seconds of the Nonchanger Postcriterion test variable scores (Table 12) indicate significant differences between these two groups for 11 variables (22 percent).

Precriterion versus Postcriterion.

T test Tables 13 and 14 state the results of a comparison of the first two seconds of Precriterion viewing scores with the scores, of the same variables, obtained during the first two seconds of Postcriterion viewing. The object of this comparison was to strengthen the assertion that the differences noted between the scores of the first two seconds of viewing, a four-second visual display, and the scores of

TABLE 11

T TESTS OF SEVENTH AND EIGHTH GRADE POSTCRITERION CHANGER SUBPOPULATION FIRST 2 SECONDS VERSUS SECOND 2 SECONDS

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Clock.	5.09	3.13	.49	1.24	.497	2.69
2nd	Low.	7.07	3.49	.54			
1st	Diag.Clock.	4.31	2.78	.43	1.09	.790	2.36
2nd	Upper	5.80	2.90	.45			
1st	Clock.	9.41	4.30	.67	1.41	.285	3.32
2nd	Total	12.87	5.10	.79			
1st	Diag.	5.14	2.54	.39	1.34	.363	2.25
2nd	Vert.Low.	6.51	2.94	.45			
1st	Vert.	10.17	3.83	.59	1.12	.730	2.60
2nd	Total	12.43	4.05	.63			
1st	L.D.,Wd.	.63	.76	.12	2.93	.001	1.85
2nd	L.D.Upper	1.07	1.31	.20			
1st	Wd.,Wd.	2.41	1.28	.20	1.00	.998	2.24
2nd	L.D.Upper	3.04	1.28	.20			
1st	Wd.,Wd.	2.53	1.30	.20	1.71	.095	4.08
2nd	L.D.,Low.	3.58	.99	.15			
1st	Wd.,Wd.	4.95	2.14	.33	1.65	.118	3.97
2nd	L.D. Tot.	6.63	1.67	.26			
1st	Wd.,L.D.	2.73	1.16	.18	1.01	.975	2.48
2nd	L.D.,Low.	3.36	1.15	.18			
1st	Wd.,L.D.	5.39	1.74	.27	1.04	.906	2.07
2nd	L.D.,Tot.	6.19	1.77	.27			
1st	Wd.,L.D.	.56	.74	.11	2.12	.020	2.50
2nd	Wd.,Upper	1.07	1.08	.16			
1st	Wd.,L.D.	1.12	1.10	.17	1.89	.047	2.67
2nd	Wd.,Tot.	1.90	1.51	.23			

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 11-Continued

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Rt. Up.	1.51	1.46	.22			
2nd	Diag.Upper	2.24	1.86	.29	1.62	.132	1.97
1st	Rt. Down	.87	1.18	.18			
2nd	Diag.Low.	1.78	1.72	.26	2.11	.020	2.76
1st	Rt. Down	1.85	1.40	.22			
2nd	Diag.Tot.	3.21	2.38	.37	2.87	.001	3.16

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 12

T TESTS OF SEVENTH AND EIGHTH GRADE POSTCRITERION NONCHANGER SUBPOPULATION FIRST 2 SECONDS VERSUS SECOND 2 SECONDS

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Horiz.	5.14	2.47	.66	2.63	.094	2.48
2nd	Lower	3.21	1.52	.40			
1st	Horiz.	10.57	3.20	.85	1.37	.579	2.66
2nd	Total	7.57	2.73	.73			
1st	Vert.	5.00	2.32	.62	1.37	.575	2.37
2nd	Lower	6.92	1.97	.52			
1st	Vert.	10.21	3.90	1.04	1.05	.927	2.34
2nd	Total	13.71	4.00	1.07			
1st	L.D.,L.D.	6.64	3.93	1.05	1.79	.306	2.18
2nd	L.D.Tot.	3.78	2.94	.78			
1st	L.D.,L.D.	3.28	1.32	.35	1.27	.673	2.71
2nd	Wd.Low.	2.00	1.17	.31			
1st	Wd.,Wd.	3.78	3.94	1.05	1.93	.249	1.92
2nd	Wd.,Low.	6.28	2.84	.75			
1st	Wd.,Wd.	2.14	1.23	.32	1.28	.664	2.44
2nd	L.D.Low.	3.35	1.39	.37			
1st	Wd.,Wd.	4.71	1.93	.51	1.33	.619	2.29
2nd	L.D. Tot.	6.28	1.68	.45			
1st	Wd.,L.D.	.42	.64	.17	2.89	.066	2.10
2nd	Wd.,Low.	1.14	1.09	.29			
1st	Rt. Dn.	.92	1.49	.39	1.29	.649	2.72
2nd	Diag.Low.	2.57	1.69	.45			

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

the last two seconds of viewing, were indeed a characteristic of this time continuum. These Tables (13 and 14) show that a small number of variables had significant differences, which supports the contention that it is something about the time continuum which causes the differences noted.

Changer subpopulation. T tests between the first two seconds of the Precriterion variable scores and the first two seconds of the Postcriterion variable scores (Table 13) indicate a significant difference between these two groups for only two variables (4 percent).

Nonchanger subpopulation. T tests between the first two seconds of the Precriterion variable scores and the first two seconds of the Postcriterion variable scores (Table 14), indicate significant differences between these two groups for only 5 variables (10 percent).

Hypothesis IIB

This hypothesis states that: the tenth and eleventh grade eye movement search pattern scores for the first two seconds of viewing, of each four-second visual display, will vary significantly from those of the last two seconds of viewing for the Precriterion and the Postcriterion tests.

The T test results shown in Tables 15-18 were derived from the tenth and eleventh grade eye movement search pattern

TABLE 13

T TESTS OF SEVENTH AND EIGHTH GRADE CHANGERS
FIRST 2 SECONDS OF PRECRITERION VERSUS
FIRST 2 SECONDS OF POSTCRITERION

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	L.D.,L.D.	6.04	1.35	.21	1.22	.530	1.77
2nd	Wd.,Tot.	5.48	1.50	.23			
1st	Lt. Up.	2.17	1.87	.29	1.95	.037	2.24
2nd	Diag.Upper	1.36	1.33	.20			

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 14

T TESTS OF SEVENTH AND EIGHTH GRADE NONCHANGERS
FIRST 2 SECONDS OF PRECRITERION VERSUS
FIRST 2 SECONDS OF POSTCRITERION

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	L.D.,L.D.	2.07	1.63	.43			
2nd	L.D. Low.	4.14	3.54	.94	4.69	.009	1.98
1st	L.D.,L.D.	3.85	2.53	.67			
2nd	L.D.Upper	2.50	1.40	.37	3.28	.041	1.75
1st	Rt. Up.	.78	1.18	.31			
2nd	Diag.Low.	2.07	2.12	.56	3.21	.045	1.97
1st	Rt. Up.	1.57	1.60	.42			
2nd	Diag.Tot.	3.71	3.40	.91	4.51	.011	2.13
1st	Rt. Down	2.00	1.61	.43			
2nd	Diag.Upper	1.00	1.35	.36	1.42	.539	1.77

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

data. All of the Methodological variables and Content variables were entered in an effort to detect variations in search patterns over time, i.e., first two seconds versus the last two seconds of viewing.

Total Population.

The total population data analysis empirically supports this hypothesis for future studies, with similar populations, due to 43 (34 percent) significant differences detected between the first two seconds of viewing and the last two seconds of viewing.

Changer Subpopulation.

The Changer subpopulation data analysis empirically supports this hypothesis for future studies, with similar populations, due to the T tests between the first two second scores of viewing, each four-second visual display, of the Precriterion test and the final two seconds of the Precriterion test, (Table 16), which indicate significant differences between these two groups for 16 variables (33 percent).

Nonchanger Subpopulation.

The Nonchanger subpopulation data analysis empirically supports this hypothesis for future studies due to the T tests between the first two second scores of viewing, each four-second visual display, of the Precriterion tests and the final two seconds of the Precriterion test (Table 15)

TABLE 15

T TESTS OF TENTH AND ELEVENTH GRADE PRECRITERION NONCHANGER SUBPOPULATION FIRST 2 SECONDS VERSUS SECOND 2 SECONDS

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Clock.	10.65	5.45	1.13			
2nd	Tot.	13.78	5.50	1.14	1.02	.970	1.94
1st	Diag.Clock.	5.00	3.86	.80			
2nd	Upper	6.82	3.38	.70	1.31	.537	1.71
1st	Diag.Vert.	4.34	2.01	.42			
2nd	Low.	7.39	3.11	.65	2.39	.049	3.93
1st	Vert.	8.39	4.15	.86			
2nd	Tot.	12.69	4.84	1.01	1.36	.475	3.23
1st	L.D.,L.D.	2.65	2.03	.42			
2nd	L.D.Upper	1.52	2.17	.45	1.14	.766	1.82
1st	L.D.,Wd.	.39	.58	.12			
2nd	L.D.,Low.	.78	.95	.19	2.66	.026	1.68
1st	L.D.,Wd.	1.00	1.04	.21			
2nd	L.D.,Tot.	1.69	1.25	.26	1.45	.388	2.04
1st	Wd.,Wd.	5.47	4.57	.95			
2nd	Wd.,Low.	2.73	2.35	.49	3.75	.003	2.55
1st	Wd.,Wd.	2.52	1.23	.25			
2nd	L.D.,Low.	3.82	1.19	.24	1.08	.862	3.64
1st	Wd.,Wd.	4.95	1.82	.38			
2nd	L.D.,Tot.	6.78	2.02	.42	1.23	.628	3.22
1st	Wd.,L.D.	2.52	1.16	.24			
2nd	L.D.,Low.	4.04	1.39	.29	1.44	.395	4.01
1st	Wd.,L.D.	4.91	1.90	.39			
2nd	L.D.,Tot.	6.47	1.78	.37	1.14	.754	2.88
1st	Wd.,L.D.	.30	.76	.15			
2nd	Wd.,Upper	.91	.90	.18	1.39	.451	2.47

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 15--Continued

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Wd.,L.D.	.73	.96	.20			
2nd	Wd.,Tot.	1.60	1.27	.26	1.74	.204	2.62
1st	Rt. Up.	.82	1.30	.27			
2nd	Diag.Upper	2.30	1.71	.35	1.74	.202	3.29
1st	Rt. Up.	2.43	1.85	.38			
2nd	Diag.Tot.	4.65	1.96	.41	1.13	.783	3.93
1st	Lt. Down	.21	.60	.12			
2nd	Diag.Upper	1.13	1.42	.29	5.64	.000	2.83

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 16

T TESTS OF TENTH AND ELEVENTH GRADE PRECRITERION CHANGER SUBPOPULATION FIRST 2 SECONDS VERSUS SECOND 2 SECONDS

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Clock.	9.13	3.49	.74			
2nd	Tot.	10.90	2.92	.62	1.43	.422	1.82
1st	Diag.	3.90	2.68	.57			
2nd	Vert.Low.	6.00	2.22	.47	1.46	.393	2.81
1st	Diag.Vert.	3.63	2.01	.42			
2nd	Upper	5.04	2.83	.60	1.99	.124	1.90
1st	Vert.	7.54	2.68	.57			
2nd	Tot.	11.04	3.88	.83	2.09	.098	3.48
1st	L.D.,Wd.	2.27	1.16	.24			
2nd	Wd. Low.	1.63	.84	.18	1.88	.156	2.07
1st	L.D.,Wd.	2.59	1.22	.26			
2nd	Wd.Upper	3.27	.93	.19	1.71	.229	2.08
1st	Wd.,Wd.	1.86	1.03	.22			
2nd	L.D.,Low.	3.27	1.07	.23	1.08	.864	4.42
1st	Wd.,Wd.	2.27	1.45	.31			
2nd	L.D.Upper	2.95	.72	.15	4.05	.002	1.97
1st	Wd.,Wd.	4.13	1.64	.35			
2nd	L.D.,Tot.	6.22	1.34	.28	1.49	.364	4.62
1st	Wd.,L.D.	2.40	1.00	.21			
2nd	L.D.,Low.	3.54	1.05	.22	1.10	.829	3.65
1st	Wd.,L.D.	4.95	1.55	.33			
2nd	L.D.Tot.	5.95	1.61	.34	1.08	.864	2.09
1st	Wd.,L.D.	.45	.59	.12			
2nd	Wd. Low.	.90	.68	.14	1.32	.534	2.35
1st	Wd.,L.D.	1.00	1.30	.27			
2nd	Wd.,Tot.	1.90	1.50	.32	1.33	.521	2.13

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Rt. Down	1.18	1.68	.35			
2nd	Diag.Low.	2.81	1.76	.37	1.10	.827	3.15
1st	Rt. Down	2.59	2.48	.52			
2nd	Diag.Tot.	4.09	2.54	.54	1.05	.912	1.98
1st	Lt. Up.	2.22	2.61	.55			
2nd	Diag.Tot.	1.13	1.39	.29	3.54	.005	1.73

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

which indicate significant differences between these two groups for 17 variables (35 percent).

Precriterion versus Postcriterion.

T test Tables 17 and 18 state the results of a comparison of the first two seconds of Precriterion viewing scores with the scores, of the same variables, obtained during the first two seconds of Postcriterion viewing. The object of this comparison was to strengthen the assertion that the differences noted between the scores of the first two seconds of viewing a four-second visual display and the scores of the final two seconds of viewing were a characteristic of this time continuum. These Tables (17 and 18) show only a small number of significant differences, which supports the contention that it is something about the time continuum which causes the differences noted.

T tests between the first two seconds of the Nonchanger Precriterion variable scores and the first two seconds of the Nonchanger Postcriterion variable scores (Table 17), indicate significant differences between these two groups for 9 variables (18 percent).

T tests between the first two seconds of the Changer Precriterion variable scores and the first two seconds of the Changer Postcriterion variable scores (Table 18), indicate significant differences between these two groups

TABLE 17

T TESTS OF TENTH AND ELEVENTH GRADE NONCHANGERS FIRST 2 SECONDS OF PRECRITERION VERSUS FIRST 2 SECONDS OF POSTCRITERION

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	C.Clock.	5.08	3.59	.74			
2nd	Upper	3.13	2.73	.57	1.72	.209	2.08
1st	L.D.,Wd.	2.56	1.59	.33			
2nd	Wd.Upper	1.78	.99	.20	2.54	.034	2.00
1st	L.D.,Wd.	5.08	1.90	.39			
2nd	Wd.,Tot.	4.04	1.74	.36	1.19	.684	1.94
1st	Wd.,Wd.	5.47	4.57	.95			
2nd	Wd.Low.	3.21	2.90	.60	2.47	.039	2.00
1st	Wd.,Wd.	2.52	1.23	.25			
2nd	L.D.Low.	1.69	.97	.20	1.62	.268	2.51
1st	Wd.,Wd.	2.43	1.23	.25			
2nd	L.D.,Upper	1.73	1.17	.24	1.11	.816	1.95
1st	Wd.,Wd.	4.95	1.82	.38			
2nd	L.D.Tot.	3.43	1.83	.38	1.01	.982	2.83
1st	Lt. Down	.21	.60	.12			
2nd	Diag.Upper	.82	1.33	.27	4.97	.000	1.99
1st	Lt. Down	1.95	2.18	.45			
2nd	Diag.Tot.	3.08	1.62	.33	1.82	.170	1.99

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

TABLE 18

T TESTS OF TENTH AND ELEVENTH GRADE CHANGERS
FIRST 2 SECONDS OF PRECRITERION VERSUS
FIRST 2 SECONDS OF POSTCRITERION

2 SECONDS	VARIABLES	MEAN	S.D.	S.E.	F.	2 TAIL	T.
1st	Horiz.	6.00	3.40	.72			
2nd	Low.	4.13	2.21	.47	2.38	.053	2.15
1st	Wd.,L.D.	2.54	1.14	.24			
2nd	L.D.Upper	1.90	1.19	.25	1.09	.852	1.81

Upper = Line Drawing in the Upper Stimulus Position
Low. = Line Drawing in the Lower Stimulus Position

for only 2 variables (4 percent).

Hypothesis III

This hypothesis states that: the eye movement search pattern scores of the Changer and Nonchanger population subdivisions will be differentially related to the Criterion variables.

The intention of this hypothesis is the generation of data relative to eye movement search patterns and to verify, by replication, the value of the Changer/Nonchanger population subdivisions.

The Changer/Nonchanger population data analysis empirically supports this hypothesis for future studies, with similar populations, in that 28 significant aptitude-treatment interactions were identified.

Correlation, Regression Slopes and Tests for Parallelism of Regression Tables.

In addition to looking at interactions between variables, it may be useful to observe what happens to a variable between different groups of subjects. Parallelism of regression analysis, in terms of comparison of group slopes, presents the data in an illustrative manner which should aid in the assimilation of the material and indicate ,in addition ,the occurrence of aptitude treatment interactions.

The pertinent information, concerning the correlations, regression slopes and tests for parallelism of regression, is presented in a tabular form designed to facilitate visual comparison. The variables presented are those with statistical significance or differences which were deemed important for other reasons.

The Criterion variables, for which correlation and parallelism of regression data are presented, are Line Drawing Success and Printed Word Success; in each table therefore, lines representing the regression slopes of the search pattern variables versus the Criterion variables, will be presented. The broken lines represent the Printed Word Criterion slopes while the solid lines represent the Line Drawing Criterion slopes. The numbers in the lower left hand corner, of each box, represent the Printed Word Criterion variable's correlation with the search pattern variable, while the number in the lower right hand corner of each box, represents the Line Drawing Criterion variable's correlation with the search pattern variable indicated.

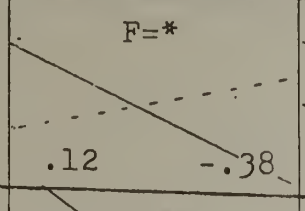
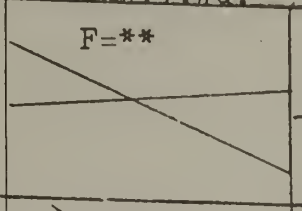
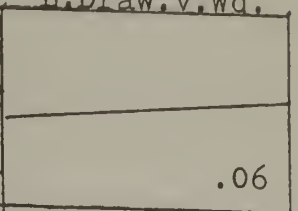
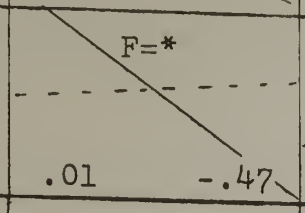
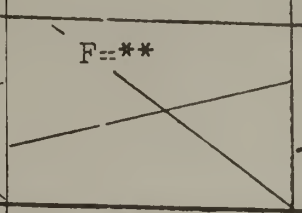
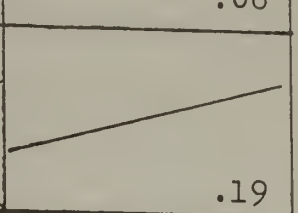
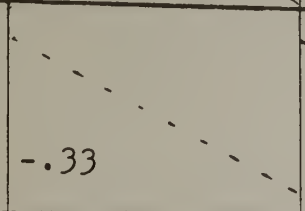
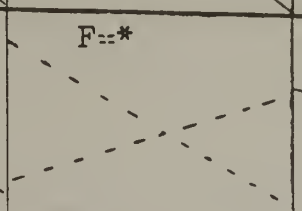
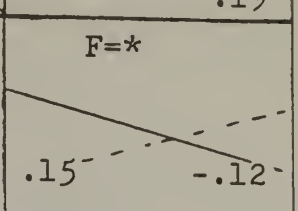
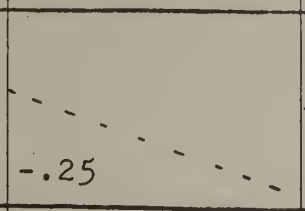
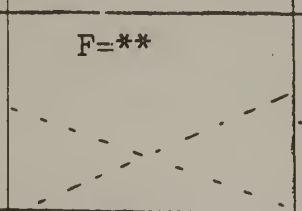
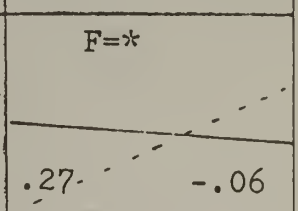
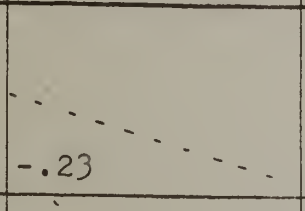
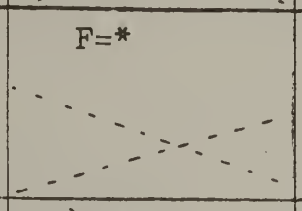
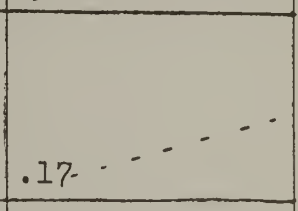
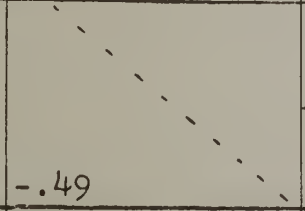
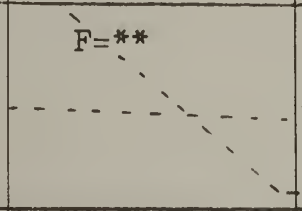
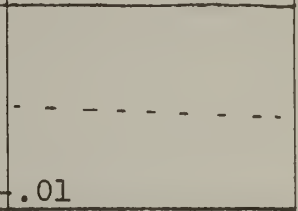
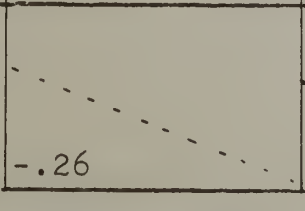
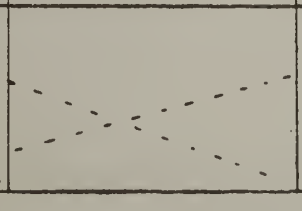
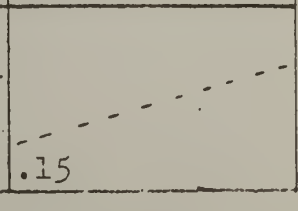
There are four columns: Variables, Nonchangers, Nonchangers-versus-Changers, and Changers. The Nonchanger column provides the regression lines, for the variable in column one, with either the Line Drawing Criterion variable (solid line) or the Printed Word Criterion variable (dotted

line) or both, if both were significant or interactive. The rightmost column provides the same information, but for the Changer subpopulation. The column headed Nonchanger-versus-Changer provides information on interaction correlation line slopes which were found to be statistically significantly nonparallel to the degree indicated by the "F" value.

Seventh and Eighth Grade Parallelism of Regression Slopes and Tests for Parallelism.

Precriterion Test. Table 19 presents data which indicates that for variable 22 (Line Drawing, Printed Word, Printed Word, Total) and variable 24 (Line Drawing, Printed Word, Line Drawing, Upper) aptitude treatment interactions (A.T.I.s) resulted between Line Drawing and Printed Word Criteria for both the Changer and Nonchanger population subdivisions. When the Changer subpopulation was tested against the Nonchanger population, statistically significant A.T.I.s were produced between the Line Drawing scores. The variables were, Line Drawing, Printed Word, Printed Word, Total; and Line Drawing, Printed Word, Line Drawing, Upper. Five other variables (Printed Word, Printed Word, Printed Word, Lower; Printed Word, Printed Word, Printed Word, Upper; Line Drawing, Printed Word, Printed Word, Lower; Clockwise, Lower; and Horizontal, Upper) showed statistically significant

TABLE 19--SEVENTH AND EIGHTH GRADE PRECRITERION REGRESSION SLOPES AND TESTS FOR PARALLELISM OF REGRESSION FOR THE LINE DRAWING AND THE PRINTED WORD CRITERION MEASURES VERSUS POPULATION SUBDIVISIONS.

Variable Number	Nonchangers (N=14) L.Draw.v.Wd.	Nonchangers v. Changers L.Draw.v.Wd.	Changers (N=41) L.Draw.v.Wd.
VAR #22-Line Drawing, Printed Word, Printed Word; Total			
VAR #24-Line Drawing, Printed Word, Line Drawing; Upper			
VAR #26-Printed Word, Printed Word, Printed Word; Lower			
VAR #27-Printed Word, Printed Word, Printed Word; Upper			
VAR #20-Line Drawing, Printed Word, Printed Word; Lower			
VAR #2 Clockwise; Lower			
VAR #9 Horizontal; Upper			

LINE DRAWING: r=Right Hand Box No., SLOPE=(——)
PRINTED WORD: r=Left Hand Box No., SLOPE=(---)
* = $p < .05$; ** = $p < .01$

TABLE 19--Continued

Variable Number	Nonchangers (N=14) L.Draw.v.Wd.	Nonchangers v. Changers L.Draw.v.Wd.	Changers (N=41) L.Draw.v.Wd.
VAR #23-Line Drawing,Printed Word, Printed Word; Total	.39	F=*	.22
VAR #14-Line Drawing,Line Drawing, Line Drawing; Lower	-.17	F=*	.20

LINE DRAWING:r=Right Hand Box No.,SLOPE=(——)
PRINTED WORD:r=Left Hand Box No., SLOPE=(---)
* = $p < .05$; ** = $p < .01$

A.T.I.s between the Changer/Nonchanger groups, for the Printed Word Criterion variable. Two variables produced A.T.I.s between the Nonchanger Line Drawing Criterion and the Printed Word Criterion. Those variables were (Line Drawing, Printed Word, Printed Word, Total; and Line Drawing, Printed Word, Line Drawing, Upper).

Postcriterion Test. Table 20 presents data which indicates a total of 8 A.T.I.s, of which 2 A.T.I.s occurred between the Line Drawing Criterion and the Printed Word Criterion in the Nonchanger subpopulation. Those variables were (Printed Word,Printed Word,Line Drawing,Total; Printed Word, Printed Word, Printed Word, Lower) and 5 A.T.I.s occurred between the Printed Word Criteria of the Changer and Nonchanger subpopulations. Those variables were (Line Drawing, Printed Word,Line Drawing,Total; Line Drawing,Printed Word,Line Drawing,Lower; Line Drawing,Printed Word,Line Drawing,Upper; Line Drawing,Line Drawing,Printed Word,Total; and Line Drawing, Line Drawing,Line Drawing,Total). There was only one A.T.I. for the Changer subpopulation and that was between the Printed Word Criteria and the variable (Printed Word,Printed Word,Line Drawing,Total).

Tenth and Eleventh Grade Parallelism of Regression Slopes and Tests for Parallelism.

Precriterion Tests. Table 21 presents data which

TABLE 20--SEVENTH AND EIGHTH GRADE POSTCRITERION REGRESSION SLOPES AND TESTS FOR PARALLELISM OF REGRESSION FOR THE LINE DRAWING AND THE PRINTED WORD CRITERION MEASURES VERSUS POPULATION SUBDIVISIONS.

Variable Number	Nonchangers (N=14) L.Draw.v.Wd.	Nonchangers v. Changers L.Draw.v.Wd.	Changers (N=41) L.Draw.v.Wd.
VAR #31-Printed Word,Printed Word, Line Drawing; Total	-.37	F=*	.26 -.02
VAR #26-Printed Word,Printed Word, Printed Word; Lower	F=* .28 -.22		
VAR #27-Printed Word,Printed Word, Printed Word; Upper	F=** .58 -.07		
VAR #25-Line Drawing,Printed Word, Line Drawing; Total	.52	F=**	-.01
VAR #24-Line Drawing,Printed Word, Line Drawing; Upper	-.22	F=**	.33
VAR #23-Line Drawing,Printed Word, Line Drawing; Lower	-.14	F=**	.32
VAR #18-Line Drawing,Line Drawing, Printed Word; Total	-.35	F=*	.10

LINE DRAWING:r=Right Hand Box No.,SLOPE=(—)
PRINTED WORD:r=Left Hand Box No.,SLOPE =(--)
* = $p < .05$; ** = $p < .01$

TABLE 20--Continued

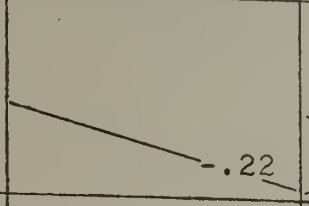
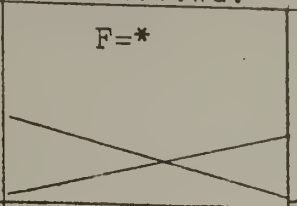
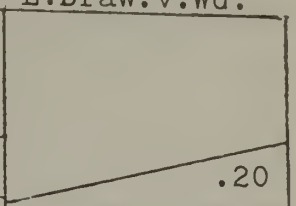
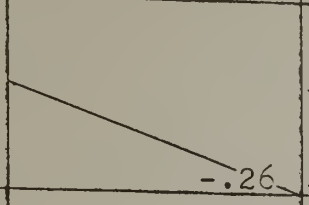
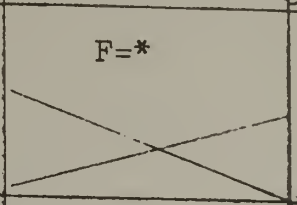
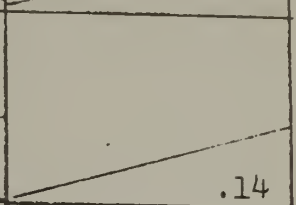
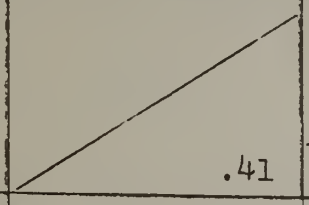
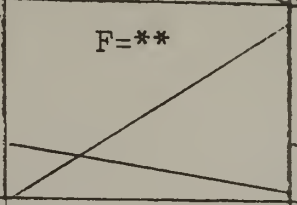
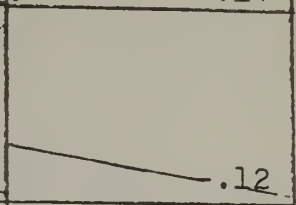
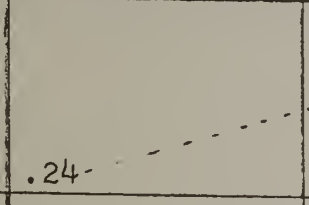
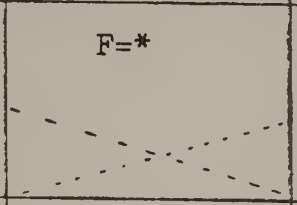
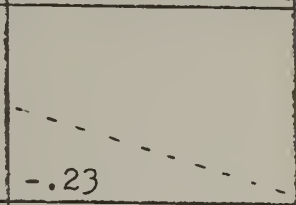
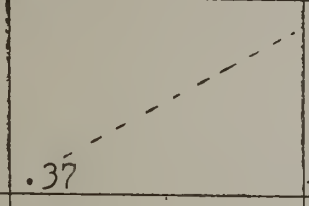
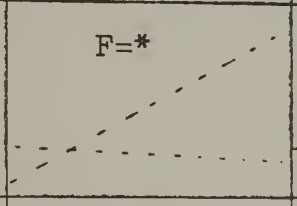
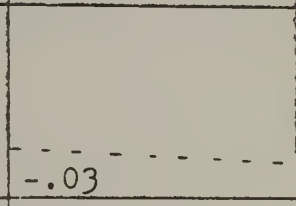
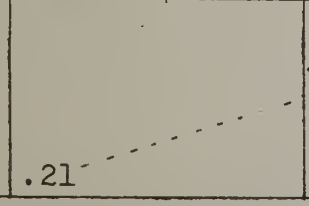
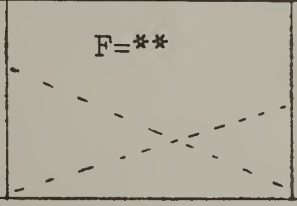
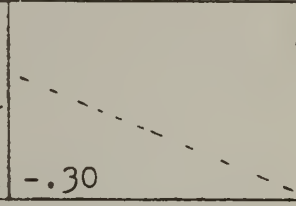
Variable Number	Nonchangers (N=14) L.Draw.v.Wd.	Nonchangers v. Changers L.Draw.v.Wd.	Changers (N=41) L.Draw.v.Wd.
VAR #16-Line Drawing, Line Drawing, Line Drawing; Total	-.38	F=*	.04

LINE DRAWING:r=Right Hand Box No.,SLOPE=(——)
PRINTED WORD:r=Left Hand Box No., SLOPE=(---)
* = $p < .05$; ** = $p < .01$

indicates a total of six A.T.I.s, of which three A.T.I.s occurred with the Nonchanger/Changer Line Drawing Criterion variable, namely (Printed Word, Printed Word, Printed Word, Total; Printed Word, Printed Word, Line Drawing, Upper; and Printed Word, Line Drawing, Line Drawing, Upper) and three occurred with the Printed Word Criterion variable, namely (Clockwise, Lower; Horizontal, Total; and Printed Word, Line Drawing, Line Drawing, Upper).

Postcriterion Test. There were no significant interactions between the Line Drawing Criterion variables and the Printed Word Criterion variables of either the Changer or Nonchanger subpopulations.

TABLE 21--TENTH AND ELEVENTH GRADE PRECRITERION REGRESSION SLOPES AND TESTS FOR PARALLELISM OF REGRESSION FOR THE LINE DRAWING AND THE PRINTED WORD CRITERION MEASURES VERSUS POPULATION SUBDIVISIONS.

Variable Number	Nonchangers (N=14) L.Draw.v.Wd.	Nonchangers v. Changers L.Draw.v.Wd.	Changers (N=41) L.Draw.v.Wd.
VAR #28-Printed Word,Printed Word, Printed Word; Total			
VAR #30-Printed Word,Printed Word, Line Drawing; Upper			
VAR #33-Printed Word,Line Drawing, Line Drawing; Upper			
VAR #2-Clockwise; Lower			
VAR #10-Horizontal; Total			
VAR #33-Printed Word,Line Drawing, Line Drawing; Upper			

LINE DRAWING:r=Right Hand Box No.,SLOPE=(——)
PRINTED WORD:r=Left Hand Box No., SLOPE=(---)
* = $p < .05$; ** = $p < .01$

C H A P T E R V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Objectives.

This study used individual eye movement fixation quantification, i.e., counts of the number of times various search pattern sequences were exhibited. The analysis of these eye movement fixations is assumed to be indicative of the information intake and processing styles of individuals, which may be related to their differential efficiency when subjected to particular paired associate learning tasks under certain environmental conditions.

This study attempted to examine eye movement data for search pattern sequences and to evaluate the relationships these sequences might have with various Ability variables.

To provide a broad base of information, two populations from the same school system were used: the students from grades seven and eight and the students from the tenth and eleventh grades.

The study also attempted to subdivide the population and the data so that information which might be hidden in total population figures could be found. This latter data is most important since it provides a basis for aptitude

treatment interaction investigation. Following historical precedent (Coffing, 1971; Caban, 1971) the population subdivisions of Changer and Nonchanger were examined for search pattern aptitude treatment interactions. Line Drawing Criterion measures versus Printed Word Criterion measures were also used for this determination.

Previous Research.

Previous research studies of this series had involved themselves with differential preferences, i.e., investigation of populations with regard to Line Drawing versus Printed Word looking or color visuals versus non-color visuals, and consistently involved the so-called Changer and Nonchanger subpopulations.

Present Research.

The present research examined the Changer/Nonchanger population subdivisions with regard to Line Drawing and Printed Word Criteria versus eye movement search pattern scores. Nonchangers were those students whose information seeking strategies, regarding Line Drawing looking versus Printed Word looking, did not change significantly between the Precriterion test and the Postcriterion test. Changers were those students whose mode of information seeking, regarding Line Drawing looking versus Printed Word looking, did change between the Precriterion test and the Postcriterion test.

Hypothesis IA

This hypothesis states that: eye movement search patterns for the seventh and eighth grade populations will correlate with selected Ability scores.

Total Population.

The total population data analysis empirically supports this hypothesis for future studies, with similar populations, for the following reasons: of the total seventh and eighth grade population, there were 197 (22 percent) significant, $p < .05$, correlations between eye movement search pattern variables and Ability variables.

Nonchanger Subpopulation. The Nonchanger subpopulation search pattern variables had 100 (12 percent) significant correlations with the Ability variables.

1. Methodological Variables. The Nonchanger Methodological search pattern variables had 57 (13 percent) significant correlations with the Ability variables.

2. Content Variables. The Nonchanger Content search pattern variables had 43 (9 percent) significant correlations with the Ability variables.

Changer Subpopulation. The Changer subpopulation search pattern variables had 87 (11 percent) significant correlations with the Ability variables.

1. Methodological Variables. The Changer, Methodological

TABLE 22

DIGEST OF SEARCH PATTERN CORRELATIONS WITH ABILITY VARIABLES

SEVENTH AND EIGHTH GRADE HYPOTHESIS IA

	Ability Variable Numbers																		
Nonchangers	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	Changers
Methodological Variables By Variable Number	12 48 49	48 49	9 12 13 48	12 13 48 49	39 47 49	42			48 49	48	9 10 39 40 47	41		8 48	9 12 13 48 49			18		No Significant Correlations

	Ability Variable Numbers																		
	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
Content Variables By Variable Number	14 26 35	14 26 35	18 20	18 20			18	18	14 16 20 22		14 16	14 24 28 33 34				21		18 19		No Significant Correlations

search pattern variables had 57 (13 percent) significant correlations with the Ability variables.

2. Content Variables. The Changer,Content search pattern variables had 30 (7 percent) significant correlations with the Ability variables.

Digest of Search Pattern Correlations with Ability Variables for the Seventh and Eighth Grade.

Table 22 is a condensation of Tables 1 and 2, 4 and 5, 7 and 8 and 10 and 11. Table 22 presents those variables which correlate $r > .30$, correlations of $r > .40$ are underlined. The $r > .30$ and $r > .40$ were used as arbitrary cutoff points to facilitate the comparison of strong correlations with Ability variables.

Changers versus Nonchangers. It should be noted that the seventh and eighth grade Nonchangers account for the bulk of the notable correlations. The Nonchangers showed a ratio of 60 to 0 when the number of correlations over $r = .30$ were compared with the Changers. It seems logical that a group which is consistent in its preference for Printed Word or Line Drawing, thereby becoming categorized as "Nonchangers," would remain consistent in its expressed preference of eye movement search strategy. This consistency of Nonchangers seems to be reflected in higher scores for some few eye movement search pattern variables. The Changers, on the other hand, seem to have lower scores for individual eye

movement search pattern variables but exhibit a greater variety of search patterns, i.e., they had spread themselves around and were inconsistent in their preferences.

The seventh and eighth grade Nonchanger Methodological variables had 13 percent more statistically significant correlations than the Nonchanger Content variables, which was not a statistically significant difference. Coffing (1971) and Caban (1971) had shown aptitude treatment interactions when using the Changer/Nonchanger population subdivisions. The Changer/Nonchanger population subdivision have again emerged as a viable and significant method of population subdivision.

Nonchanger Subpopulation. Variables 48 and 49 (Left Down Diagonal, Upper, and Left Down Diagonal, Total, respectively) show strong correlations with some Ability variables. Variable 12 (Vertical, Upper) correlates with four Ability variables and variable 13 (Vertical, Total) correlates with three Ability variables. Variable 9 (Horizontal,Upper) shows three correlations. Variable 8 (Horizontal, Lower) shows one strong correlation with the Ability variables. There were 34 (7 percent) methodological correlations above $r = .30$.

Changer Subpopulation. There were no correlations

$r > .30$ for the Changer subpopulation.

S.R.A. Variables. The S.R.A. tests (variables 81-84) were administered only to the seventh and eighth grade. Analysis of the Methodological variables and the Content variables with relation to the S.R.A. variables, follows:

1. Methodological Variables. Of the Methodological variables, the Mathematics S.R.A. tests (variables 83 and 84) showed correlations with eight Methodological variables, three variables more than with the S.R.A. variables 81 and 82, which were the Reading variables.

2. Content Variables. The Content variables, while not as strong in the number of correlations, showed six variable correlations with the Reading variables which was two more than with the Mathematics variables.

Conclusion. Though the differences shown between the Methodological variables and Content variables, when correlated with the S.R.A. Ability variables were not statistically significant, a direction seems indicated. The student with the greater number of Methodological correlations seems to score higher in the Mathematics S.R.A. tests. The student exhibiting a greater number of Content variable correlations seems to score higher in the Reading S.R.A. tests.

E.T.S. Variables. Variables 91 and 95 (Hidden Figures Part A and Extended Range Vocabulary Part B) each showed correlations with 5 Methodological variables. The Content variables differed markedly in that variables 89 and 92 (Surface Development Part A and Hidden Figures Part B) correlated most frequently.

Conclusions. This marked difference in correlations could well indicate population subdivisions which could have prognostic value.

Line Drawing in the Lower Stimulus Position versus Line Drawing in the Upper Stimulus Position. The ratio of Line Drawing in the upper Stimulus Position correlations to Line Drawing in the Lower Stimulus Position correlations was a 6-to-1 preference for the Line Drawing in the Upper stimulus position.

Conclusion. Considerable attention should be focused upon Line Drawing in the Upper Stimulus Position versus Line Drawing in the Lower Stimulus Position presentations in future research.

Hypothesis IB

This hypothesis states that: eye movement search patterns for the tenth and eleventh grade populations will correlate with selected Ability variables.

Total Population.

The total population data analysis empirically supports this hypothesis for future studies,with similar populations, for the following reasons: of the total tenth and eleventh grade population there were 192 (21 percent) significant, $p < .05$, correlations between Eye Movement Search Pattern variables and Ability variables.

Nonchanger Subpopulation.

The Nonchanger subpopulation had 142 (16 percent) significant correlations with the Ability variables.

1. Methodological Variables. The Nonchanger Methodological variables had 60 (11 percent) significant correlations with the Ability variables.

2. Content Variables. The Nonchanger Content variables had 83 (15 percent) significant correlations with the Ability variables.

Changer Subpopulation.

The Changer subpopulation had 50 (9 percent) significant correlations with the Ability variables.

1. Methodological Variables. The Changer Methodological variables had 19 (4 percent) significant correlations with the Ability variables.

2. Content Variables. The Changer Content variables had 31 (5 percent) significant correlations with the Ability variables.

Digest of Search Pattern Correlations with Ability Variables for the Tenth and Eleventh Grade (Table 23).

Changers-versus-Nonchangers. It is noteworthy that the Nonchanger population was involved in 17 correlations $r > .30$, while the Changer population had just 1 correlation.

Methodological and Content Variables Compared. When the arbitrary cutoff point of $r > .30$ was used (see Table 23) many of the significant correlations reported in Tables 5-8 were eliminated. The Nonchanger Methodological variables correlated with the Ability variables (85-99) only 3 times, whereas the Nonchanger Content variables correlated 14 times. There were 5 Content variables, of the Nonchanger population, correlated at $r > .30$, with variable 91 (Hidden Figures Part A). This is in contrast to the Methodological variables which had 0 correlations at the $r > .30$ level with variable 91.

Comparison of the Seventh and Eighth Grade Correlations with the Tenth and Eleventh Grade Correlations. (Tables 22 and 23).

Variable 91. By far, variable 91 (Hidden Figures, Part A, of the E.T.S. French Test) had more variable interactions, for both age groups, than any other Ability variable. Variable 91 has had a history of strong correlations (Caban, 1971; Walker, 1973). The fact that this effect survives, what may be a test of maturation in this study, makes it a prime candidate for future eye movement studies. It is noteworthy

TABLE 23

DIGEST OF SEARCH PATTERN CORRELATIONS WITH ABILITY VARIABLES

TENTH AND ELEVENTH GRADE HYPOTHESIS IB

	Ability Variable Numbers																		
Nonchangers	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	Changers
Methodological Variables By Variable Number									8				42						42	Only VAR #38 Correlated with Ability VAR #91

	Ability Variable Numbers																		
	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Content Variables By Variable Number								31 29		28	19 20 22 29 31		30 31 34			27			15 16

No Significant Correlations

that variable 91 held its prime position even though in the seventh and eighth grade it was correlated with the Methodological variables and in the tenth and eleventh grade it was correlated with the Content variables.

Conclusion. Variable 91 should be investigated in any future, similar,research, as it seems not only to be interactive with search pattern variables, but also to keep its interactivity over time (age). Since such a clear population split was evidenced between the Methodological variables versus the Content variables, regarding variable 91, it may well produce aptitude treatment interactions (A.T.I.s). A.T.I. development between the seventh and eighth grade and the tenth and eleventh grade was not undertaken as part of this research.

Loss of Interactions. The loss of interactions involving Methodological variables with relation to the tenth and eleventh grade population, requires analysis. Although there were 64 percent fewer significant correlations with the tenth and eleventh grade population than with the seventh and eighth grade population, the loss occurred disproportionately with reference to the Methodological and Content variables. The Methodological variables seem to have lost their holding power by losing 91 percent of their significant correlations. Aging, or some other factor, occurring between

the eighth grade and the tenth grade, seems, in this study, to have eroded the value of the Methodological search pattern strategy. However, if one considers the number of tenth and eleventh grade correlations, and the fact that some students do exhibit a strong preference for the Content variables whereas the rest of the students do not, it becomes possible that researchers might identify a distinct subpopulation among these subjects which may prove valuable in future studies and may well produce A.T.I.s.

Age as a Factor in Consistency. According to Table 22 & 23 both of the age groups showed correlations for the Nonchanger population almost exclusively.

1. Comparison of Nonchanger Methodological Variables. The Methodological, Nonchanger, eye movement search patterns for the tenth and eleventh grades showed only 3 correlations compared with 34 for the seventh and eighth grade methodological Nonchangers.

2. Comparison of Nonchanger Content Variables. The seventh and eighth grade had 26 correlations while the tenth and eleventh grade had 14 correlations. These 14 correlations, however, represented 80 percent of all of the correlations that the tenth and eleventh grade had.

3. Conclusion. It seems that the Content variables were more enduring over the two age groups' correlations with the Ability variables in this study. Also the data seems

to indicate, assuming all confounding variables static, that aging may have resulted in a shift from a Methodological approach to a Content approach. The students seem much more interested in getting, from each projected quadrant, the information from the Printed Word or Line Drawing, than in processing in any predetermined order. What seems to be maturation may have created students who are less stylized in their approach to learning and more "picky" regarding what they will look at, and for how long, in order to get the information they need. Whatever other changes aging may have produced, a shift in the inequity of the Changer/Nonchanger correlations was not one of them. It can be conjectured that a Nonchanger person is more set in his "modus operandi" than his counterparts. This might lead him to set or stylized procedure, which in turn could produce higher correlations for certain modes of operation, e.g., Content search patterns.

Hypothesis IIA

This hypothesis states that: the seventh and eighth grade eye movement search pattern for the first two seconds of viewing,of each four-second visual display, will vary significantly from those of the last two seconds of viewing for the Precriterion and Postcriterion tests.

Total Population.

The total population data analysis empirically supports this hypothesis for future study due to 31 cases (16 percent) of significant variation between the first two seconds of viewing and the last two seconds of viewing.

Changer Subpopulation.

When a comparison, using T tests, of the first two seconds of viewing, for the seventh and eighth grade Changer subpopulation, was made with their last two seconds of viewing, the number of significant differences amounted to 17 cases (of a possible 48) for the Precriterion test data (see Table 9) and 16 cases (of a possible 48) for the Postcriterion test data (see Table 11).

Nonchanger Subpopulation.

When comparison, using T tests, of the first two seconds of viewing, for the seventh and eighth grade Nonchanger subpopulation, was made with their last two seconds of viewing, the number of significant differences occurring in the Precriterion test data (Table 10) amounted to 14 cases (of a possible 48) and the Postcriterion test data (Table 12) accounted for 11 cases (of a possible 48).

Precriterion versus Postcriterion.

Table 13 compared the first two seconds of the Changer subpopulation, Precriterion test with the first two seconds

of the Changer, Postcriterion test, and shows only 2 significantly different variable scores. Table 14, which compares the Nonchanger subpopulation, Precriterion test, first two seconds, with the Nonchanger subpopulation, Postcriterion test, first two seconds, shows only 4 variables significantly different.

Summary.

Tables 9-12 all indicate significant differences between the first two seconds of viewing and the last two seconds of viewing. Tables 13 and 14, however, indicate little difference between the first two seconds of viewing of the Precriterion test when compared with the comparable data of the Postcriterion test. This seems to indicate that the search patterns exhibited during the first two seconds,of even diverse eye movement stimulus material, are much more similar, than the first two seconds of viewing compared with the last two seconds of viewing of the same material. The implications seem quite important. Perhaps four seconds of viewing each visual is too long. The four second eye-fixation data, if subdivided, may provide entirely different information. Perhaps some of the first two second data is abrogating the value of other parts of the four second viewing data, or vice versa.

The most plausible explanation seems to be that there is

something about the last two seconds of viewing, be it Precriterion test, Postcriterion test, Changer or Nonchanger, which creates a problem of consistency regarding these seventh and eighth grade students. Mooney (1958) has shown that a large part of the recognition process takes place during the first instants of visual exposure. Could these T test results be an indication of habituation or boredome, or some other effect, in some individuals during the last two seconds of exposure? Enoch (1960), Grether (1950) and others have noted that the first fixations remain fixated longer than those following. Perhaps speed of recognition is what has been encountered in these T test findings. Also, the speed of cognition seems to be related to the speed of recognition, Anderson (1958), Enoch (1960). If so, a powerful diagnostic tool may be available to the future investigator. This aspect of eye movement research seems to demand continued attention from future researchers.

Hypothesis IIB

This hypothesis states that: the tenth and eleventh grade eye movement search pattern scores for the first two seconds of viewing, of each four-second visual display, will differ significantly from those of the final two seconds of viewing, for the Precriterion and Postcriterion tests.

Total Population.

The total population data analysis empirically supports this hypothesis for future studies with similar populations due to 43 (22 percent) significant differences detected between the first two seconds of viewing and the last two seconds of viewing.

The T test results shown in Tables 15-18 were derived from the tenth and eleventh grade eye movement search pattern data. All of the Methodological variables and Content variables were entered in an effort to detect variations of search patterns over time, i.e., first two seconds versus the final two seconds.

Nonchanger Subpopulation.

T tests between the first two seconds of the Nonchanger Precriterion variable scores and the last two seconds of the Nonchanger Precriterion variable scores (Table 15), indicate significant differences between these two groups for 17 (35 percent) variables.

Changer Subpopulation.

T tests between the first two seconds of the Changer Precriterion variable scores and the last two seconds of the Changer Precriterion variable scores (Table 16), indicate significant differences between these two groups for 16 variables (33 percent).

Precriterion versus Postcriterion Tests.

T test Tables 17 and 18 present the results of a comparison of the first two seconds of Precriterion viewing scores with the scores of the same variables, obtained during the first two seconds of Postcriterion viewing. The object of this comparison was to strengthen the assertion that the differences noted between the scores of the first two seconds of viewing and the scores of the last two seconds of viewing of a four-second visual display were a characteristic of this time continuum. These Tables (17 and 18) show a very small number of significant differences which supports the contention that there is something about the time continuum which causes the differences noted. The subjects seem to process, at least where Search Pattern variables are concerned, more in accord with time than with content. The same visual produced statistically different data when the first two seconds of eye movement Search Pattern data was compared to the last two seconds of such data. However, two different visuals showed hardly any search pattern variables which differed. Clearly, researchers must investigate these results.

Hypothesis III

This hypothesis states that: the eye movement search

pattern scores of the Changer and Nonchanger population subdivisions will be differentially related to the Criterion variables.

Table 19 provides data regarding the seventh and eighth grade Precriterion eye movements of the Changer/Nonchanger population subdivisons, and Line Drawing and Printed Word Criterion measures.

Precriterion Tests.

It may be noted that the Precriterion tests of seventh and eighth grades produced a few more aptitude treatment interactions (A.T.I.s) than did the Precriterion tests of the tenth and eleventh graders, i.e., 9 A.T.I.s versus 6 A.T.I.s, respectively.

Postcriterion Tests.

The Postcriterion tests of the seventh and eighth graders produced 8 A.T.I.s but the Postcriterion tests of the tenth and eleventh graders produced only 2.

Summary.

Even though both groups were from the same school system, any definite statements about the significance of the results would be dangerous to make due to a myriad of potentially confounding variables, e.g., just one teacher, somewhere between the eighth and tenth grade, could have had an unusual effect on the entire group. However, the

following conjectures are brought to mind, based upon the concept of aging. Do older students process more quickly and do they then bore more easily? Does increased age bring with it conservatism? Do mature students process differently than they did before and in what way differently? Some form of long-term study may be needed to answer these questions.

Changer/Nonchanger Population Subdivision.

The Changer/Nonchanger population subdivisions produced almost equal numbers of A.T.I.s. However, different variables were involved with each group. Further eye movement research into the patterns of relationships with each group is indicated.

Aptitude Treatment Interactions.

The fact that significant aptitude treatment interactions continue to be produced by eye movement researchers, could mean that educational research is much closer to tailoring the "method to the man" than ever. Researchers could be dealing with Ability and process variables for which new names will have to be invented. The tailoring of the learning environment to the student's predispositions, seems an obvious step toward greater efficiency of learning, i.e., more learned with less time and effort expended. These factors could, if implemented, cause students to regard

learning as a challenge, and a hopefully worthwhile endeavor, rather than an offensive chore. Could students be searching for alternate forms of instruction which are not, at present, available to them? Must all students acquiesce to the same mode of instruction, when for some students this mode may be the most difficult one possible? In providing an aptitude treatment interaction indicator, eye movement research may aid in enabling the educator to match systems for learning to the student.

Summary of Conclusions

Hypotheses IA and IB.

For both the seventh and eighth grade and the tenth and eleventh grade population's search patterns enough statistically significant correlations with the Ability variables were found to support the argument that search pattern analysis might be considered a viable idiosyncratic assessment procedure.

Changers-versus-Nonchangers. Both the Changer and Nonchanger population subdivisions provided groups with definitive characteristics relative to individual assessment.

Methodological-versus-Content Variables. Both Methodological and Content, search pattern subdivisions, provided idiosyncratic information.

Educational Relevance. Search pattern analysis, in this study, has shown promise as an idiosyncratic assessment method relative to educational processes.

Hypotheses IIA and IIB.

For both the seventh and eighth grade and the tenth and eleventh grade populations, the time versus data (first two seconds of eye movement data versus the last two seconds of eye movement data) analysis, has provided much information regarding the student's use of his eyes during elapsing time. Both groups, the seventh and eighth, and the tenth and eleventh, seem to indicate significant differences, regarding eye movement Search Patterns, when looked at from the standpoint of elapsed time. Since in past research this lack of continuity of the subjects and their eye movement data, was not known, considerable misleading data may have been used.

Changers-versus-Nonchangers. The difference between the first two seconds of viewing, of a four-second display, and the last two seconds of viewing, did not seem to be related to the Changer/Nonchanger population subdivision. The Changers and the Nonchangers, as groups, had about the same differences between the first two seconds and the last two seconds of viewing.

Educational Relevance. Since this data indicates

considerable difference in variable scores between the first two seconds of viewing and the last two seconds of viewing, researchers will be challenged how best to use the information. Analysis of eye movement data, both past and future, from the time continuum aspect, seems mandatory. Results previously achieved, in eye movement studies, using the total four-second scores, may well be strengthened by exorcising potentially irrelevant or misleading data. In the future data may be subdivided, into time continuum based categories, which may have idiosyncratic assessment value.

Hypothesis III.

For both the seventh and eighth grade and the tenth and eleventh grade populations, there were aptitude treatment interactions (A.T.I.s) between the Changer/Nonchanger subpopulations, and the Printed Word and Line Drawing Criterion variables. The seventh and eighth grade population had 17 (66 percent) more A.T.I.s than the tenth and eleventh grade population. The tenth and eleventh grade Postcriterion data yielded no A.T.I.s whatever.

Educational Relevance. Aptitude treatment interactions seem to hold considerable promise relative to tailoring the learning environment to the student. It is for this reason that A.T.I.s are sought after with vigor in idiosyncratic

research. The occurrence of A.T.I.s between the Criterion variables and the eye movement Search Pattern variables could be of major importance. The information that the seventh and eighth grade population had the A.T.I.s with the eye movement Search Pattern variables and the tenth and eleventh grade population did not will need investigation by future research to determine the probable cause. Those A.T.I.s which have been discovered, in this series of studies, should be of great value in the structuring of idiosyncratic learning environments.

Limitations of the Findings

It must be remembered that exploratory studies do not result in conclusions, but indicate relationships which then need to be retested for confirmation; correlation does not imply causation.

Variable Overlap.

For each subject there were 240 eye fixation pictures which were then subdivided into 24 Content variables. Since each Methodological variable is drawn from the same data pool as the Content variables, some overlapping could occur which would affect the comparison of the Methodological variable counts when compared with the Content variable counts. This study did not test for this effect.

Various Confounding Variables.

Minor variations in any of the following could cause some variation in individual performance: the male voice on the introduction tape; almost anything about the conditions of the data collection, e.g., the environmental setting, eye movement machine, the size of the projection, the format, etc.; the experience (history) of these students with previous testing, Hawthorne effect, etc., etc., etc.

Puberty.

Seventh and eighth grade students are just entering puberty, whereas the tenth and eleventh graders are just asserting their young adulthood; comparison between these two groups should consider these factors potentially uncontrolled variables which may have some bearing upon the results.

Unrecognized Bias.

Every experimenter prefers, secretly, for one conclusion to an experiment over others. Despite the utmost care and diligence, those involved in this experiment may have built in some factors which would prejudice the results. This threat is mentioned only to show cognizance of this possibility. No such bias is known to have influenced the results. Great effort was made to remain objective.

Suggestions for Future Studies

Changer Status.

This study used a Changer determination based upon a fifty percent cutoff point. An eye movement study, the aim of which would be the determination of the Changer/Nonchanger cutoff point which would maximize the production of treatment interactions, clearly demands to be done.

Coffing (1971), Caban (1971), this research, and the research studies of Marilyn Harris and John Packer, doctoral students at the University of Massachusetts (degrees pending), all show the Changer/Nonchanger population subdivision to be viable regarding A.T.I. production. As soon as a study to determine the most productive group assignment for the Changer/Nonchanger population subdivision has been done, the next research step could be an in-depth investigation of the aptitude treatment interactions produced using these revised population subdivisions.

Aptitude Treatment Interactions.

In view of the continued success in achieving aptitude treatment interactions with the Changer/Nonchanger population subdivisions it would seem promising to initiate a study which, after dividing the population, would actually revise the treatment of the subjects and try to achieve greater efficiency of learning.

Replication.

There have been a series of eye movement studies, each different, but also, in many ways redundant. A study using each of the previous studies as a subpopulation might well yield data useful in guiding future eye movement studies. This study would be facilitated by the use of standardized recording of eye movement data.

Long-Range.

A long-range study, over as great a span of time as possible, of eye movement in general and search patterns in particular, of one population, seems to hold considerable promise of producing much information.

Variations.

Eye movement technology has been vastly simplified and improved, however, the present series of eye movement studies have used about the same paired associate stimulus and response format throughout; sequential testing, using the same population but with different visual formats, i.e., larger, smaller, six pair, eight pair, etc., could lead to more information.

First Two Seconds versus the Second Two Seconds.

The great difference between the first two second eye movement search pattern scores and the last two second search pattern scores, seems most promising as an avenue for future

studies. This hypothesis, for which there seems to be little precedent in eye movement studies, may be a breakthrough which could lead to increased usefulness of eye movement studies by minimizing the effect of what may be counter-productive, misleading eye movements which are presently being used.

Additional Thoughts

Promise.

Should the first two seconds versus the last two seconds research yield distinctive population subdivisions, and the Changer/Nonchanger research manage to subdivide the population further, as well as produce substantive correlations and meaningful aptitude treatment interactions, then eye movement may well move from the research stage into the realm of practical application as a tool for defining idiosyncratic differences.

Conservation of Time.

It should be noted that the per-student testing time was about seven minutes. Even if that time span were not shortened, we seem to have garnered a large quantity of information in a very short period of time.

At the moment, however, the transfer of the data, from the eye movement films onto sheets and then onto IBM cards,

is very time-consuming and laborious. A study whose major thrust is the conservation of time used in processing the eye movement data would make eye movement, as a research tool, more palatable to researchers. Should eye movement prove usable as a diagnostic tool those using it will need a faster method by which to transfer the data.

Summation

This series of eye movement studies may be breaking new ground in the search for idiosyncratic reactions to stimuli. The thought of being able to prescribe a "best": presentation mode, learning environment, or learning sequence, etc. depends heavily upon an educator's idiosyncratic assessment capability. Though no milestone in the individual assessment field, the present research has added the prospect of another viable tool, namely eye movement search pattern analysis, to the researcher's arsenal. In time that arsenal may enable us to increase learning efficiency on an individual student basis. What a truly marvelous idea!

A P P E N D I X I

Script for Slide Tape Presentation to Subjects

This experiment involves remembering things that are grouped together in pairs:

Learning in pairs SLIDE 1

It is not difficult, but it will require your full concentration. You will be presented with pairs of things that must be remembered together. For example, you might hear the sentence, "The brick breaks the window."

The brick breaks the window SLIDE 2

At the same time you will see helpful information on the screen in front of you. A number of these pairs will be presented. These will be called, "Pairs to Remember."

Pairs to Remember SLIDE 3

Try to remember as many as possible.

In the test part, you will then be asked to name out loud the second part of a pair when you are presented with the first part. In our example when the brick

Brick SLIDE 4

is presented alone, you should answer out loud "window." To repeat, you are asked to study each of the pictures of paired objects, "Pairs to remember," as they appear on the screen, while listening to the verbal description of the

Pairs to remember SLIDE 5

objects in order to learn which objects are presented together. You will be asked to name the missing object in each pair when shown the other object of that pair.

Pairs SLIDE 6

Now look at each number in turn as I call them:

1, 2, 3, 4, 5 SLIDE 7

Number One. Number Two. Number Three. Number Four. Number Five.

Now you will be presented the first set of slides.

Pairs to Remember SLIDE 8

The carrot taps the barrel. SLIDE 9

The foot kicks the School. SLIDE 10

The bat breaks the cup. SLIDE 11

The hair fills the pipe. SLIDE 12

The hand throws the hat. SLIDE 13

The iron melts the candy. SLIDE 14

Now give your answers out loud.

Test	SLIDE 15
Iron	SLIDE 16
Foot	SLIDE 17
Bat	SLIDE 18
Carrot	SLIDE 19
Hand	SLIDE 20
Hair	SLIDE 21

Now here is the second set to remember:

Pairs to Remember	SLIDE 22
The doll opens the book.	SLIDE 23
The letter strikes the beans.	SLIDE 24
The wheel spins the fish.	SLIDE 25
The can marks the butter	SLIDE 26
The spoon rolls the egg.	SLIDE 27
The fork cuts the cake.	SLIDE 28
The fire burns the bed.	SLIDE 29
The celery hits the stairs.	SLIDE 30
The guitar occupies the sink.	SLIDE 31
The rock cracks the bottle.	SLIDE 32
The arm holds the break.	SLIDE 33
The shovel lifts the popcorn.	SLIDE 34

TEST	SLIDE 35
Fire	SLIDE 36
Doll	SLIDE 37
Spoon	SLIDE 38
Guitar	SLIDE 39
Can	SLIDE 40
Shovel	SLIDE 41
Letter	SLIDE 42
Wheel	SLIDE 43
Celery	SLIDE 44
Rock	SLIDE 45
Fork	SLIDE 46
Arm	SLIDE 47

Now here is the third set for you to remember

Pairs to Remember	SLIDE 48
The ruler divides the sandwich.	SLIDE 49
The elephant kicks the clock.	SLIDE 50
The button rubs the comb.	SLIDE 51
The string secures the box.	SLIDE 52
The cow jumps the tent.	SLIDE 53
The clown chews the banana.	SLIDE 54
The needle pops the balloon.	SLIDE 55
The rope touches the eye.	SLIDE 56
The dog closes the gate.	SLIDE 57

The car upsets the wagon. SLIDE 58

The frog leaps the cage. SLIDE 59

The blanket covers the tree. SLIDE 60

Now give your answers out loud.

TEST SLIDE 61

Needle SLIDE 62

Ruler SLIDE 63

Cow SLIDE 64

Dog SLIDE 65

String SLIDE 66

Blanket SLIDE 67

Elephant SLIDE 68

Button SLIDE 69

Rope SLIDE 70

Car SLIDE 71

Clown SLIDE 72

Frog SLIDE 73

And here is the last set to remember.

Pairs to Remember SLIDE 74

The tractor smashes the mask SLIDE 75

The stick strikes the rice. SLIDE 76

The towel dries the plate. SLIDE 77

The marble bumps the thump. SLIDE 78

The swing nicks the bathtub. SLIDE 79

The hammer pulls the bell. SLIDE 80

Now give your answers out loud.

TEST SLIDE 81

Hammer SLIDE 82

Towel SLIDE 83

Marble SLIDE 84

Stick SLIDE 85

Swing SLIDE 86

Tractor SLIDE 87

Thank you for helping us. The operator will now remove your headstrap. Thank you again.

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